COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

September, 1946

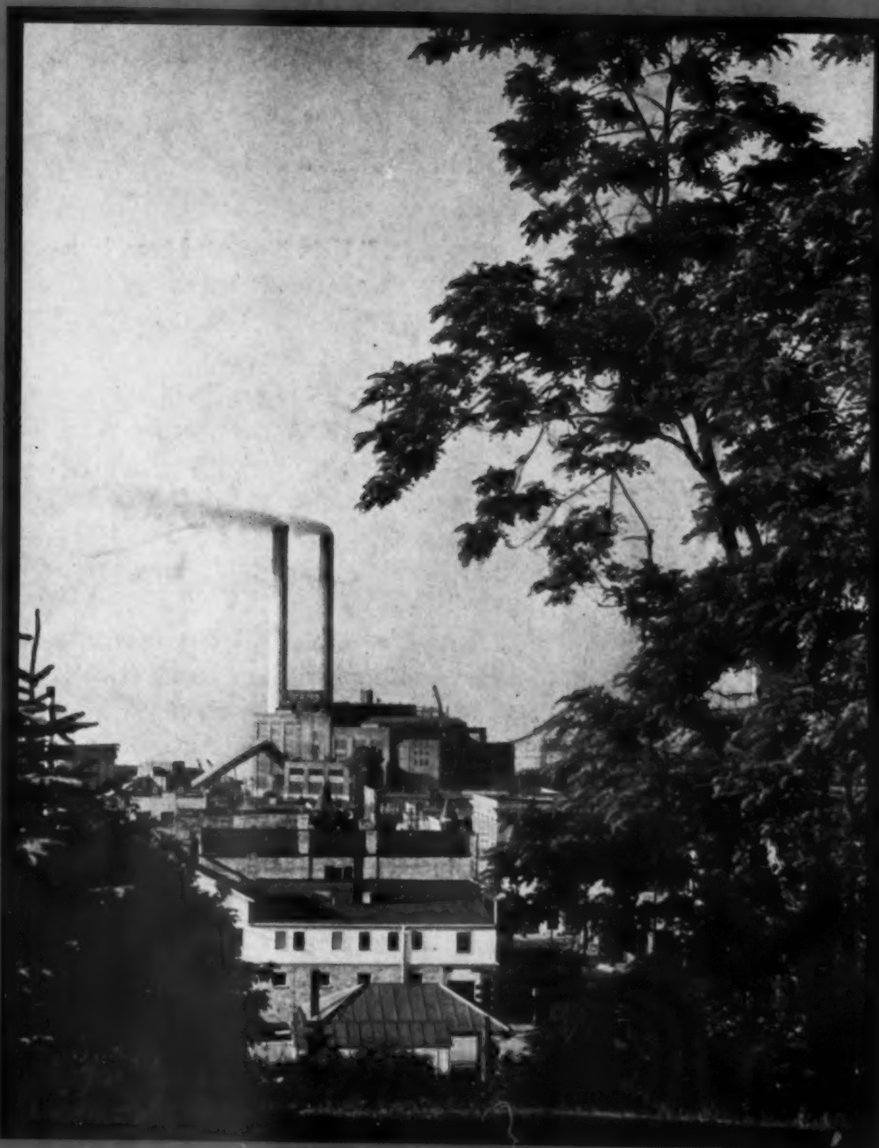

Photo by H. R. Towse

THE CONDENSATE PUMP

Recirculation of Sludge

By-Product Steam Supplements Chemical Recovery in Paper Making

Recent C-E Steam Generating Units for Utilities

CECIL LYNCH STEAM-ELECTRIC STATION

ARKANSAS POWER & LIGHT COMPANY

THE C-E Unit, illustrated here, is now under construction at the new Cecil Lynch Steam-Electric Station of the Arkansas Power & Light Company at North Little Rock, Arkansas.

It is designed to produce 325,000 lb of steam per hr at 920 psig and a total temperature of 905 F.

The unit is of the "outdoor" type, roofed over above and completely weather-proofed. It is designed for natural gas and oil firing and is equipped with 6 horizontal, combination burners. The boiler is a 3-drum, bent tube type with Elesco 2-stage superheater. A thermostatically controlled bypass damper assures superheat temperature control over a wide range of rating. The furnace is completely water cooled, using closely spaced plain tubes. A Ljungstrom Air Heater, located at the rear of the unit, at ground level, supplies preheated combustion air to the burners.

This station, which employs a one-boiler one-turbine arrangement, is structurally similar to the Harvey Couch Station built at Stamps, Arkansas, by the same company in 1943.

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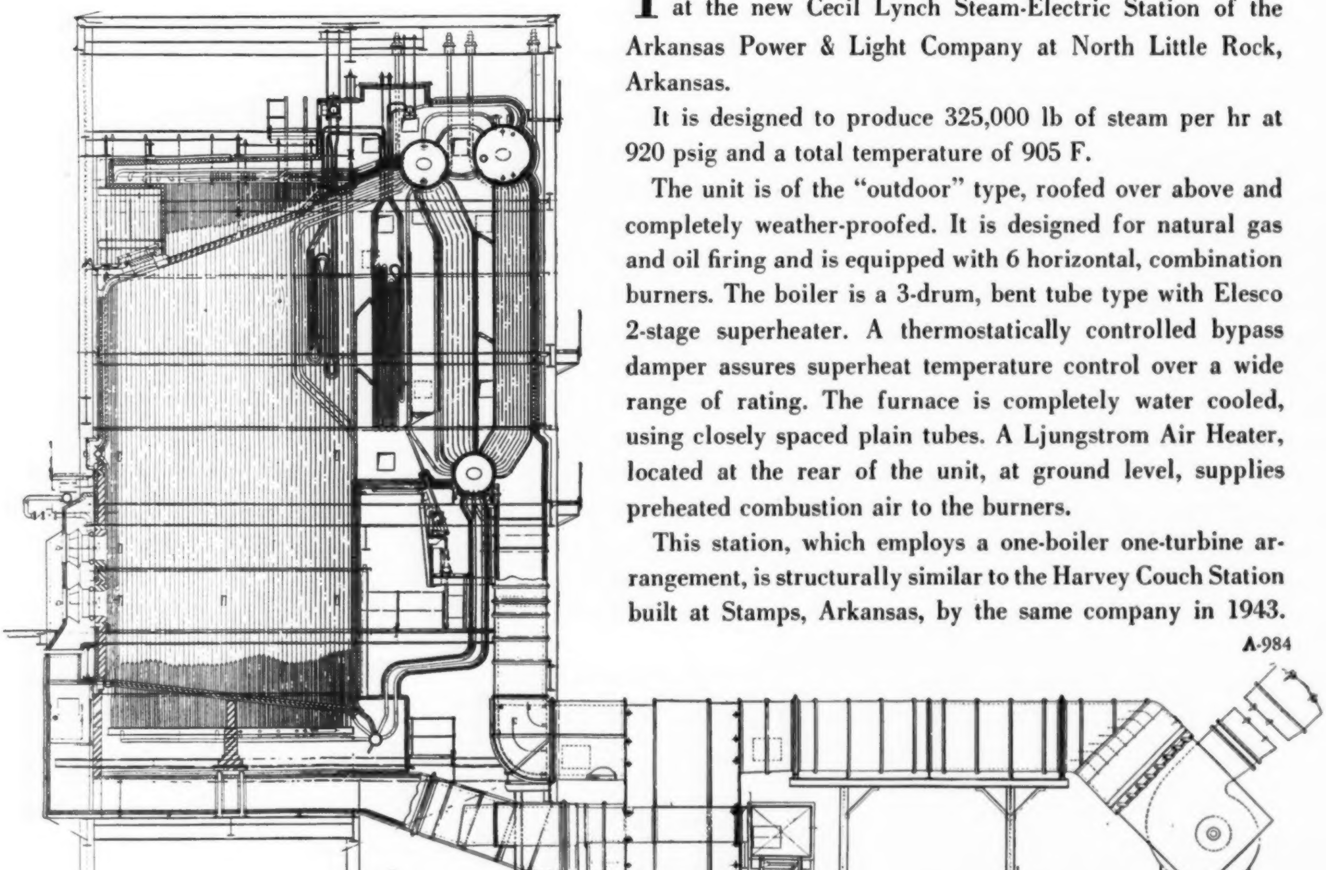

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VOLUME EIGHTEEN NUMBER THREE

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EDITORIAL

A Worthwhile Report

Bituminous Coal Research, Inc., among its numerous activities, has issued a revised report on the application of overfire jets to prevent smoke from stationary boiler plants.

Of course, overfire jets, both air and steam, have been used for many years; and their effectiveness in combating smoke with both hand and stoker firing has long been recognized. While some such installations were engineered, many others were made without proper knowledge, and economy of operation was sacrificed. However, it remained for Bituminous Coal Research to undertake a systematic study of the subject as a research project at Battelle Memorial Institute, Columbus, O. The report, issued in pamphlet form under the authorship of Richard B. Engdahl, who was responsible for most of the laboratory and field work, is a thoroughly practical analysis of the problem. It contains specific information on the design and construction of both steam and air nozzles, their location for different types of stokers, instructions for their installation, the quantities of overfire air required, selection of blowers, typical performance and operating suggestions. In other words, it provides the essential information for the successful application of air and steam jets and the checking of those already in use.

Although it is now common practice to install overfire air or steam jets to provide necessary turbulence with certain type of new stokers, there are numerous older installations that do not have them, as well as many hand-fired furnaces. It is these older plants that are often the worst offenders as smoke producers, and they can profit greatly by the information contained in the report. Furthermore, the present coal situation is in some cases conducive to smoke through inability of the user to acquire the coal best suited to the plant requirements. In such cases, overfire air or steam jets are likely to be most helpful. They have also been used on an estimated thousand locomotives.

Offsetting Increased Fuel Costs

After a progressive decrease for more than twenty years, the average coal consumption per kilowatt-hour output by electric utility plants in this country has remained at a nearly static figure of about $1^1/_3$ pounds for the past five years. Meanwhile the price of coal has steadily mounted and is likely to increase further—a fact that has made many plant designers and operators efficiency conscious.

Had the war not intervened, it is likely that by this time the above figure would have been lowered somewhat by a greater number of new and more efficient plants having been placed in service; but under present conditions of materials supply it will probably be a couple of years before there is a significant change in this average.

As the margin for further improvement in the performance of individual stations narrows, designers are re-examining all factors having bearing thereon. Already new stations have been laid down for total steam temperatures of 1000 to 1050 F, and some engineers are advocating increased cycle efficiency by employing a greater number of extraction stages for higher feedwater temperature. However, there are many who object to the latter expedient.

A third proposal toward achieving increased efficiency is to regain more of the heat that now goes up the stack by the introduction of more heat-recovery surface. Although the lower temperature of the stack gases introduces a potential corrosion problem it is anticipated that this may be combatted by taking advantage of metallurgical advances.

Another trend, exemplified in some new designs, is still lower gas velocities entering the superheater in order to minimize slagging and a reduction in the amount of baffling so as to reduce baffle maintenance and simplify design. While this does not bear directly on thermal efficiency, it does concern operation, particularly labor and outage.

Whatever means are adopted in the individual case to offset the increasing cost of coal, as well as other operating expenses incident to its quality, one must always look beyond thermal gains to the overall dollar economy measured over a substantial period. Herein lies the soundness of employing conservative design.

Electric Output Indicates Substantial Production

Output of electric energy has long been considered an excellent index of industrial activity. If this be accepted, it would appear from the latest figures compiled by the Federal Power Commission that, despite many interruptions due to labor troubles and the apparent scarcity of commodities in many lines, total production for the month of July, 1946, was not far behind that of the same month last year when the war was still in progress.

According to these figures the output of utility plants, both private and public owned, for last July was not only the highest since VJ Day but was only 1.8 per cent below July 1945. The output by private industrial power plants, based on reports from concerns representing some 85 per cent of the total, extended to represent 100 per cent coverage, was off 3.1 per cent. This is probably due to a number of war production plants not yet converted. However, the combined utility and industrial output of electric energy was off only 2.1 per cent.

The Condensate Pump

By LEWIS J. DAWSON Field Engineer
Ingersoll-Rand Co., Cameron Pump Division

The author describes the mechanical features that must be incorporated in a satisfactory condensate pump design, and performance of the pump as related to the power plant system; materials, vents, etc., are also briefly discussed.

THE condensate pump is a necessary and important auxiliary in the power plant. Its function of removing the condensate must be performed under a rather unusual set of conditions. This article will attempt to define these conditions, and to explain the design and operational features attendant to this type of service.

Requirements of Pump Design

The condensate pump takes suction from the condenser hotwell and therefore must draw water from a source under approximately 28 in. vacuum. As the hotwell water is close to saturation conditions, the only net positive suction head available at the pump is that which is obtained by the submergence or the vertical distance between the hotwell water level and the centerline of the pump impeller eye. The available net positive suction head, hereafter abbreviated NPSH, is all-important in the design of the impeller and the performance of the pump.

In the primary equation of flow, $Q = A\,V$, it can be seen that the flow Q is dependent on the factor A, which in

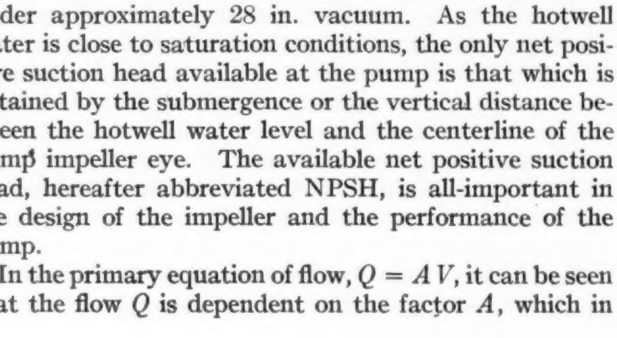

Fig. 1—Effect of NPSH on pump performance

this case is the area of the impeller eye, and the factor V, the velocity of flow through the eye. The second factor may be reduced further to

$$V = \sqrt{2gh}$$

so that by substitution

$$Q = A\sqrt{2gh}$$

From the above it can be deduced that for any given impeller eye area A, the maximum flow is limited by the factor h, which is the available NPSH. To look at it from the standpoint of mechanics, there must be a force to accelerate the water into the impeller eye, and this force is furnished by the pressure head.

Fig. 1 shows the performance of a typical centrifugal pump under various NPSH conditions. It can be seen that the head-capacity curve breaks off at decreasing

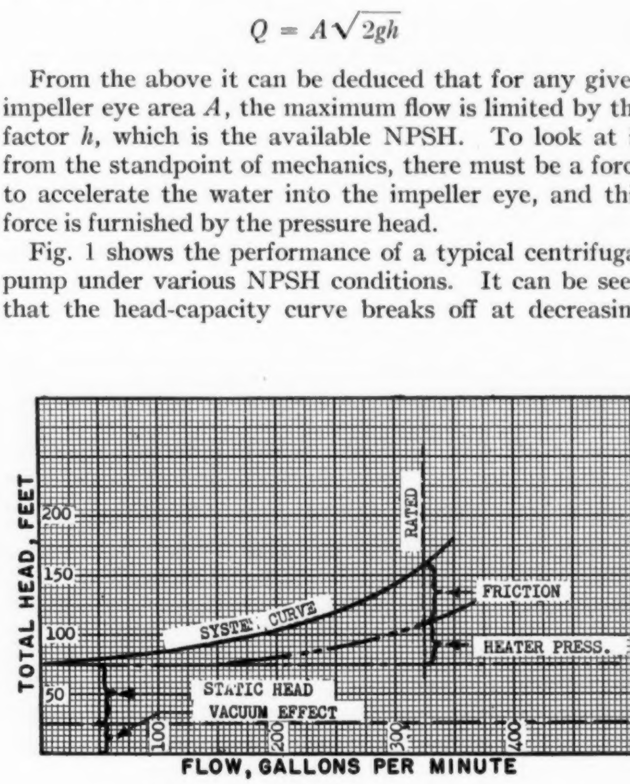

Fig. 2—Condensate system curve

capacities as the NPSH is reduced. In the illustrated case, the maximum flow obtainable with 5 ft NPSH is 375 gpm, whereas with only 3 ft NPSH, the maximum capacity is reduced to 250 gpm. The "break off" is caused by flashing into vapor of some of the liquid entering the impeller and is usually accompanied by noise. The characteristic sound resembles that of gravel passing through the pump.

Condensate System Curve

The total head against which the condensate pump must work is the sum of the vacuum effect existing at the pump suction plus the discharge head. The latter factor consists of static elevation from the pump to the point of discharge, friction in the discharge piping and system, and vapor pressure in the vessel to which the condensate discharges. Fig. 2 shows a graphical representation of a typical system in which the condensate discharges into a deaerating heater. Vacuum effect at suction is 25 ft, static lift to the heater is 50 ft. Heater shell pressure from extraction steam is 35 ft at full load conditions, decreasing with load, but pegged at atmospheric pressure as a minimum. The resulting system curve has a minimum value of 75 ft, which represents static lift plus

vacuum effect, and gradually rises with increased capacity caused by increased system load.

When the discharge line contains a regulator, the effect is to increase the friction of the system and consequently to steepen the system curve at partial loads. The system curve under the influence of a discharge regulator will actually be a family of curves originating from a common point at zero flow.

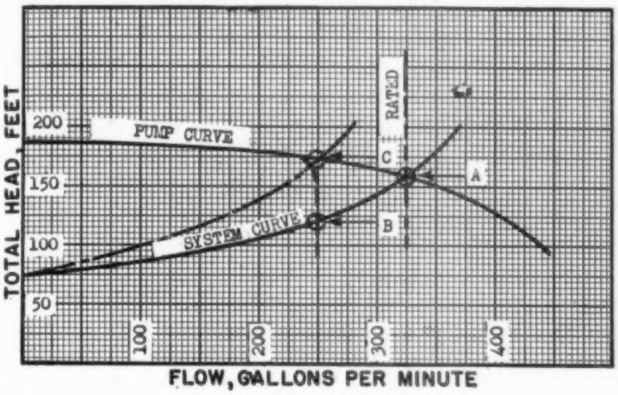

Fig. 3—Pump and system curves showing types of regulation

Regulation

Fig. 3 shows the pump curve superimposed on the system curve. The pump curve and system curve must always intersect at the actual flow condition. When the pump condition point is selected to correspond to the head condition at rated flow on the system curve, the intersection of the curves will have to occur at rated capacity. This point is represented by *A* on Fig. 3.

At loads less than rated conditions, the actual operating point depends on the type of system regulation. When the pump discharge contains no regulator, a decrease in system load will cause a reduction of the total head against which the pump must deliver. The pump then tries to deliver more water than is entering the hotwell as condensate, causing the hotwell liquid level to be drawn down, which continues until the NPSH is just sufficient to allow the pump to deliver the reduced flow. In effect, the pump is "breaking off" so that its characteristic now follows the dashed line on Fig. 3. Operation stabilizes at point *B*, and the pump is said to be "regulating on the suction side." As explained previously, this "breaking off" is the result of partial flashing of the liquid entering the first-stage impeller, resulting from reduced NPSH. At any other flow condition less than rated capacity, the hotwell level and amount of flashing will adjust themselves to cause the break-off curve to pass through the actual flow point on the system curve.

When a discharge regulator is used, the pump characteristic remains constant and the system friction curve is altered to intersect the pump curve at the actual flow condition. If the system flow decreases, the pump tries to deliver more water than is entering the hotwell, and the level in the hotwell tends to fall. The float control then causes the pump discharge to be throttled until the system friction curve intersects the pump curve at the revised flow condition. This point is represented by *C* on Fig. 3. The pump is said to be "regulated on the discharge side," and no flashing need occur at the first-stage impeller eye. The hotwell level is maintained within a small range.

When multi-stage condensate pumps are regulated on the suction side, the pressure distribution among stages will vary with flow. The flashing in the first-stage impeller decreases the head developed in this stage, and at very light loads the first stage will do no work. Under these conditions, the first-stage discharge vent will show a vacuum. Severe and continued flashing in the first stage may cause rough operation of the pump due to unequal distribution of water in the impeller, which causes the impeller to be out of dynamic balance. There is also the possibility of cavitation of the impeller metal due to the repeated hammer-like blows of condensing vapor bubbles. The rotor will also be out of endwise balance due to the absence of pressure in the first stage.

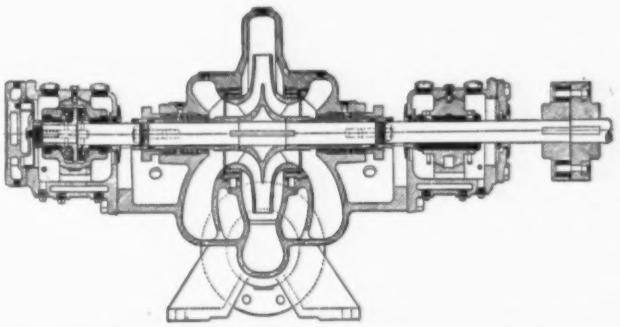
Fig. 4—Single-stage, double-suction pump for low and moderate heads

Types of Condensate Pumps

While it is possible to use many types of centrifugal pumps for condensate service, there are a few special types that have proved the most satisfactory and are generally used. For low and moderate heads, a single-stage, double-suction pump is satisfactory. Fig. 4 shows a pump of this type. The pump as shown is equipped with journal bearings and gravity-type lubrication to the thrust bearing. The suction passages on both sides are tapped for vents. To prevent air inleakage through the packing, the stuffing boxes are

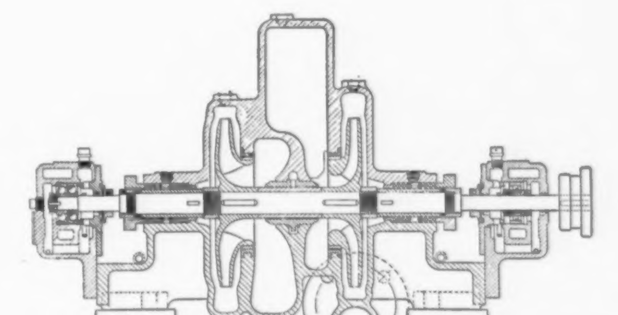
Fig. 5—Two-stage axially balanced pump

equipped with cages for external seal water. Air leakage between the shaft sleeve and shaft is prevented by two rings of packing in a counterbore at the outside end of the shaft sleeve.

For higher heads, a multi-stage arrangement is required. Fig. 5 shows a two-stage pump axially balanced by having the impellers faced in opposite directions. The suction chamber is equipped with a vent to prevent accumulation of noncondensable vapors in the chamber. The stuffing boxes are normally under discharge pressure from the first and second stages, respectively, but due to the fact that regulation on the suction side may cause no pressure to be developed, it is necessary to provide seal cages in the stuffing boxes. The external seal will also prevent air in-leakage on an idle pump.

For larger capacities and higher heads a pump as shown in Fig. 6 is suitable. Although there are four impellers, it is actually a three-stage pump, as the two center impellers are arranged in parallel. This arrangement provides double the eye area, and also permits axial balance by having two impellers faced in each direction. Here again the suction chamber is equipped with a vent, and stuffing boxes are externally sealed.

To obtain the necessary NPSH for a horizontal condensate pump, it is often necessary to install the unit

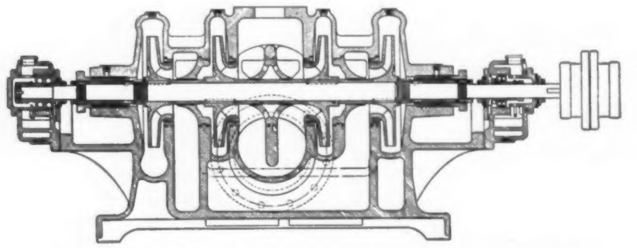

Fig. 6—Pump for large capacities and high heads

in a dry pit. Such a pit requires extra excavation and cost and there is always danger of flooding the motor. Where sufficient submergence is a design problem, a pump such as shown in Fig. 7 is available and offers a good solution. This unit is a multi-stage pump installed in an outer barrel, the top of which is fitted with a nozzle head. The suction nozzle connects to the space within the outer barrel and around the outside of the pumping element proper. The unit is installed with the nozzles just above floor level, with the outer barrel sunk into the floor. As the first stage is at the bottom of the pumping element, the NPSH available is the total distance from the hotwell water level to the entrance of the first-stage impeller. The motor is at the top of the unit, with little danger of flooding. Any number of stages can be added to meet the required head. The last-stage impeller discharges to the pump column, which connects with the discharge nozzle in the head.

Fig. 8 shows a special vertical condensate pump built in large numbers for marine service. Vertical arrangements are preferred for marine service due to limited floor space. The rotor of the pump is guided by one external and one internal radial bearing, the thrust being taken by the driver. The arrangement of first-stage impeller with inlet upward provides a free exit for any vapor or noncondensable gases which may be liberated at the inlet.

Materials

Pump materials have been the subject of much discussion in recent months, particularly with reference to boiler feed pumps handling very pure and unbuffered water. Although the condensate passing through the

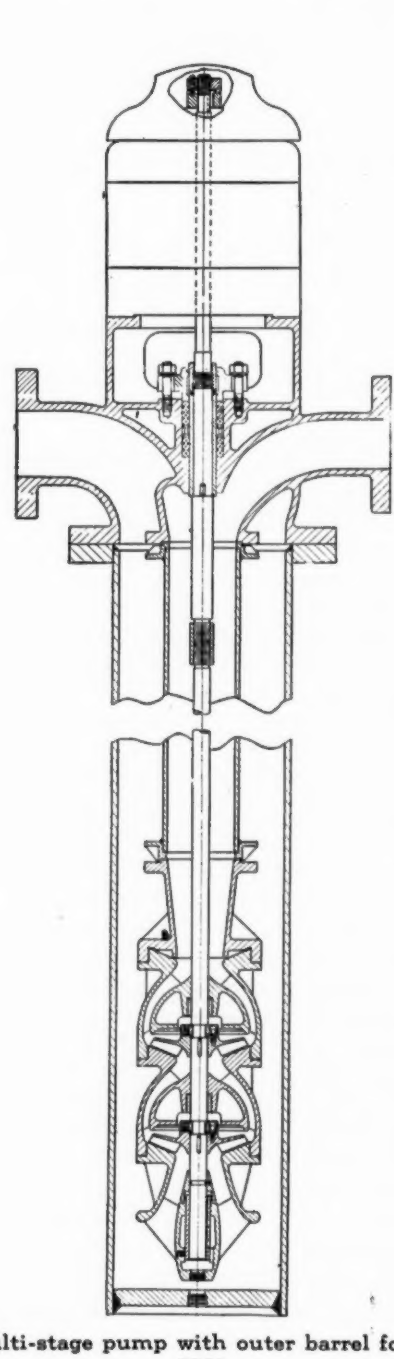

Fig. 7—Multi-stage pump with outer barrel for submergence

hotwell pump is just as pure and unbuffered, the low temperature of the water makes it much less corrosive. In general, regular fitted pumps are satisfactory for condensate service. Such a pump is fitted with a cast-iron casing, bronze impellers and rings. Carbon steel is satisfactory for the shaft in most cases.

Suction Line

The condensate pump suction line should be laid out to give a short and smooth flowing path between the hotwell and pump. A short line is desirable to keep the friction losses to a minimum as these losses mean less NPSH for a given submergence. As the formation of vapor, the entrainment of vapor and of noncondensable gases are inevitable in the suction pipe, the line should have no horizontal runs or pockets. If a lateral run is required in the layout, it should be given a slight pitch toward the hotwell so that the vapors tend to go back to the condenser.

Lateral runs should be made at the highest pressure point in the suction line. The pipe should drop vertically from the hotwell and then proceed laterally to the pumps, so that the lateral run has the benefit of the vertical static head to prevent flashing. If the lateral run is installed prior to the vertical leg, the pressure above the vapor point of the water is small and the least disturbance will cause vapor to form. Large amounts of vapor thus formed may accumulate in "blobs" and cause complete separation of the water column.

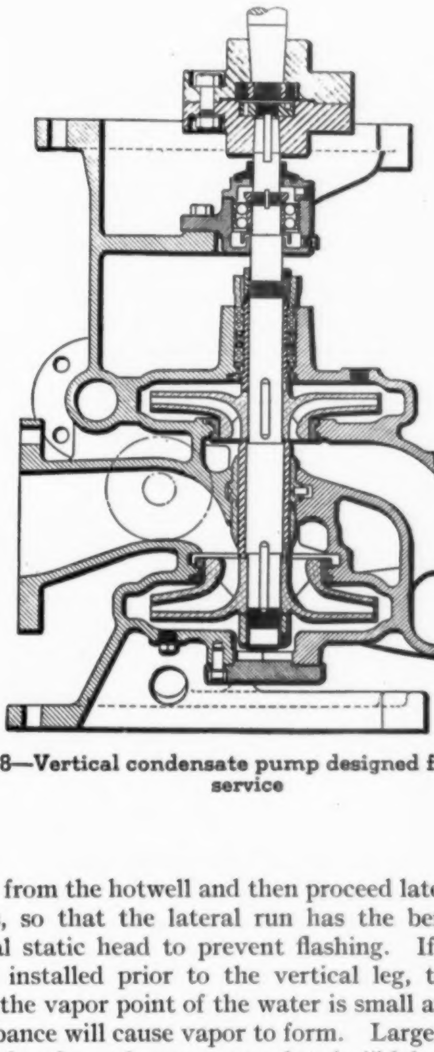

Fig. 8—Vertical condensate pump designed for marine service

Vents

Vent lines should be piped to the vapor space of the condenser and the line should have a continuous slope from the pump to the condenser. Needless to say, the vent line must be of adequate size to pass any accumulation of vapors which is likely to occur under the existing conditions.

The need for suction vents varies with the type of installation and type of unit. In any unit where there is a chance for vapor to collect in the vicinity of the first-stage impeller eye, the installation of a vent line is always advisable.

Heater Drip Pumps

Heater drip and drain pumps may be considered a specialized type of condensate pump. Submergence and NPSH may be as low as in a condensate unit but usually the location of the heater allows greater static head on the suction. If the drain pump is to operate at high temperature, special features must be provided, such as water-cooled stuffing boxes and smothering-type glands. Fig. 9 shows a vertically split process pump which is designed for hot liquids and is therefore excellently suited to high-temperature drain service. The pump is of the overhung cradle type with a self-venting vertical suction nozzle. The shaft is carried in oversize ball bearings, which are ring-oiled from a large water-cooled oil sump.

Regulation of heater drip and drain pumps is similar to that of condensate pumps, as previously discussed. However, the units are of smaller capacity and therefore more easily vapor bind under suction conditions which cause flashing. Therefore, a discharge regulator, float-controlled from the heater hotwell, is generally used. The heater hotwell should be of sufficient capacity to prevent wide variations in level with change of load conditions.

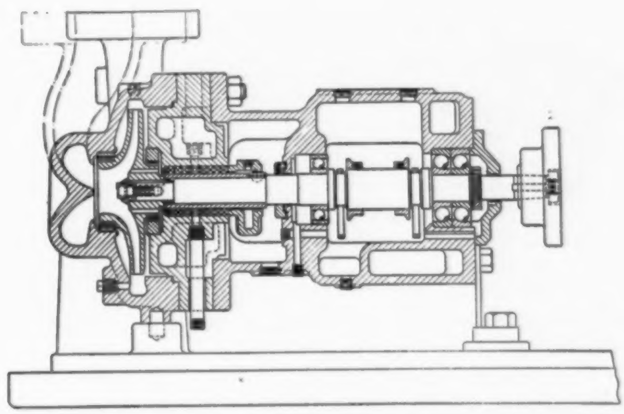

Fig. 9—Vertical pump designed for high-temperature service

Materials for heater drain pumps handling hot water must be selected with the same consideration given boiler feed pumps. The heater drain will be typical unbuffered water and therefore corrosive to cast iron and carbon steel. The use of corrosion-resistant materials, such as bronze, Ni-resist, monel and stainless steel or similar alloys is indicated.

In conclusion, it can be said that the modern condensate pump, properly selected, built and installed, should be one of the most trouble-free pieces of equipment in the power plant. Normal maintenance will always be required and should not be overlooked. Such details as oil changes, attention to stuffing boxes and coupling lubrication should be routine. Internal inspection should not be required unless performance is off or there are indications of the existence of improper mechanical conditions.

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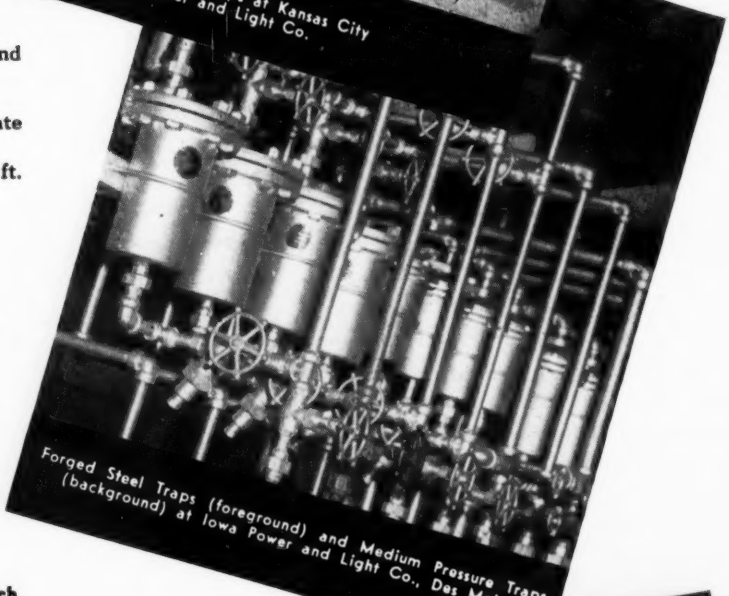

Forged Steel Traps (foreground) and Medium Pressure Traps (background) at Iowa Power and Light Co., Des Moines.

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RECIRCULATION OF SLUDGE

By C. E. JOOS
Cochrane Corporation

When applied to hot-process softeners to condition relatively soft waters for the removal of silica, the recirculation of sludge improves the performance. The author discusses the amount to be recirculated, describes the mechanism employed and quotes results from several typical examples.

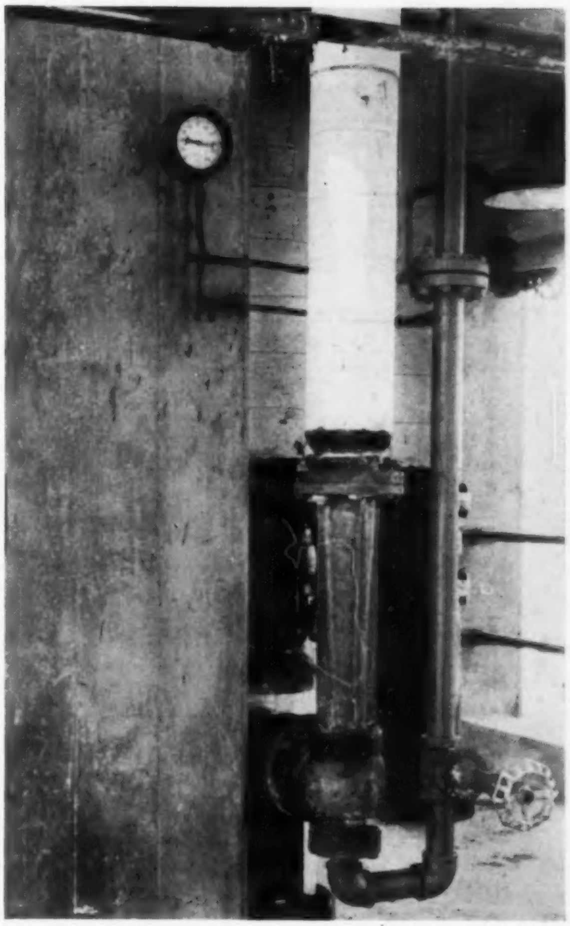

Fig. 1—Eductor installed for recirculation of sludge in hot-process water conditioning. Valve in water inlet is adjusted by reference to duplex pressure gage mounted across orifice plate ahead of valve

THE practice of recirculating a portion of the precipitated hardness or sludge in cold-process softening and clarifying equipments to accelerate reactions and to improve the clarity of the effluent is not new. The writer is familiar with the practice from first-hand experience as far back as 1916, while literature and patents indicate its value was recognized in the latter part of the 19th century.

It is worthy of note that the methods then proposed for the improvement of the cold-process equipments were very similar to the procedures now followed, although not generally incorporated in equipment as a matter of design until recently.

At the present time there is a growing appreciation of the value of sludge recirculation, as a result of which it has been incorporated in cold-process water-conditioning equipments on a carefully engineered basis and represents the most important design feature to obtain optimum results. In these equipments the scientific approach has improved precipitation to such a degree that better clarity of water is obtained in approximately one-quarter the retention time. The improvement is so marked that it has rendered obsolete the conventional cold-process softener utilizing a retention time of four hours.

With the hot-process softener, which has usually been applied to very hard waters, the need has not been so great nor the improvement so marked. In this equipment the temperature at which the reactions take place is such that they are completed almost instantaneously provided the chemicals and water are intimately mixed. The one-hour retention time is normally sufficient for satisfactory floc growth and efficient settling of the precipitate in a properly designed sedimentation tank.

In recent years, however, the application of the hot-process softener has been extended to condition relatively soft waters for the removal of silica, and operation in one or two stages to precipitate the hardness to zero. Under these circumstances sludge recirculation is advantageous. In softening a relatively low hardness water the precipitated hardness may not be sufficient to properly coagulate turbidity. The increase in bulk of precipitate by recirculation of sludge is necessary for thorough clarification.

In the removal of silica the effectiveness of the chemicals can be greatly increased by the recirculation of sludge to expose such precipitates as magnesium hydrate to the water for longer periods and thus bring about greater efficiency of adsorption. With the recirculation of sludge under these circumstances a saving in chemicals amounting to 25 per cent can be attained. Putting it another way, the recirculation of sludge improves the performance of the hot-process softener in the adsorption of silica when no silica adsorbing chemicals are introduced for that specific purpose.

In the operation of two-stage hot-process softeners the water is given a treatment of lime and soda ash in the first stage for the purpose of reducing the hardness to the order of 10 to 15 ppm. Then the effluent is delivered to a second tank section built integral with the first, or to

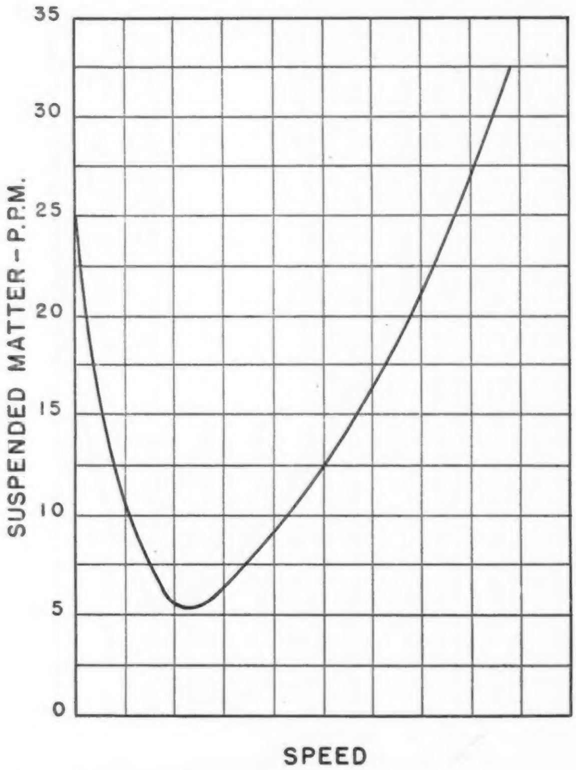

Fig. 2—Relation of speed of stirring mechanism to suspended matter and the effluent of the hot-process water softener sedimentation tank

an independent tank where phosphate is added in the form of disodium phosphate, monosodium phosphate or phosphoric acid, for the purpose of reducing the remanent hardness to zero.

Under certain circumstances the turbidity, largely calcium carbonate, may react with the phosphate reagent causing increased alkalinities and increased phosphate consumption. It is for this reason that it is highly desirable to reduce the turbidity from the first stage to very low values.

In view of the fact that boiler pressures are increasing, water tubes becoming smaller, and with the economic necessity for low boiler outage, it is highly desirable to improve the performance of the hot-process softener. For this reason the two-stage softener under these circumstances is becoming increasingly popular. The residual hardness is reduced to almost infinitesimal values resulting in elimination of sludge accumulation in the boilers. Under proper operating conditions the hardness can be reduced to values of less than one-half ppm and several plants report hardness values of 0.07 ppm as determined on a large volume sample by quantitative determinations.

Amount of Sludge to Be Recirculated and Method Employed

The amount of sludge to be recirculated will obviously depend upon plant conditions, but for a water having a hardness of 10 grains per gallon or more, the amount will probably not exceed 2 per cent. This is the ratio of the volume of sludge to the amount of water entering the unit. In one plant very satisfactory results were obtained when this sludge quantity was only 0.7 per cent of the influent. Generally speaking, the figure of 2 per cent should meet all needs.

The consistency of the sludge may vary, but usually this contains approximately 13 to 15 per cent of solids by weight.

There are a number of methods by which sludge can be satisfactorily recirculated and some of these are as follows:

1. By direct pumping.
2. By an eductor utilizing the raw water or treated water as the energizing force.
3. Delivery of the sludge from the sludge cone to the chemical proportioning equipment, making use of the chemical feed pump to serve the double function of recirculation and chemical feeding.

The most popular method of recirculating sludge is by the use of a small open impeller pump taking the sludge from the sludge cone and delivering it with the chemicals to the top of the sedimentation tank. It is sometimes considered that the high-speed action of the pump will break up the floc and thus reduce the efficiency of the precipitate; but in the writer's experience this does not seem to have any basis in practical operation for most of the sludges are quickly reformed even after passing through pumps, throttling orifices or throttling valves.

Use of an eductor is considered by some to have the advantage of not so readily breaking up the floc. While this appears to be an academic question, the eductor, nevertheless, has been applied to a number of installations. Fig. 1 illustrates an eductor for taking the sludge from the sludge cone and delivering it to the top of the

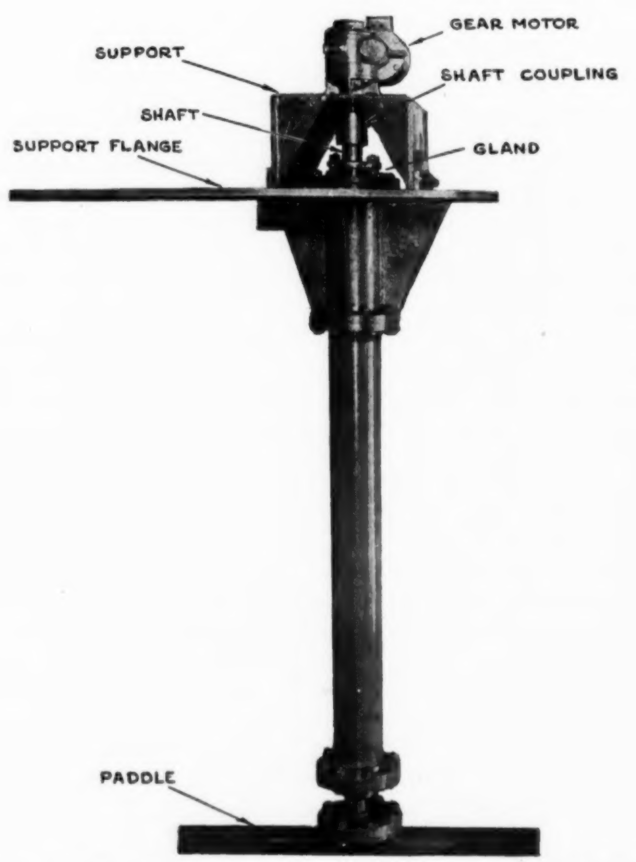

Fig. 3.—Stirring mechanism assembly consists of a slowly rotating paddle driven through a gear reducer by an electric motor

sedimentation tank, utilizing raw water ahead of the regulating valve as the energizing force. The amount of sludge to be recirculated is governed by regulation of the water flow through a valve as indicated by a duplex gage across an orifice in the inlet line. This method of recirculation has been highly satisfactory and is very simple.

Stirring Mechanism

Along with the development of sludge recirculation there has also been developed a stirring mechanism which creates a rotary motion within the sedimentation tank and brings about improvement in the rapidity of floc formation and better sedimentation. The stirring mechanism is a motor-operated device in which the flat blade is rotated at the optimum speed. This speed is dependent upon the tank diameter.

A number of tests, involving many installations of the stirring mechanism, have indicated exceptionally fine performance with fairly hard waters without sludge recirculation. With relatively soft waters it is recommended that sludge recirculation be combined with the stirring mechanism.

Fig. 2 illustrates the performance of the stirring mechanism and particularly its critical value as to speed, for if the stirring mechanism is operated at too high a speed the tank will be stirred up so greatly as to decrease the efficiency of sedimentation, whereas if the speed is not up to the optimum only partial improvement is obtained. With this simple device turbidities of the sedimentation tank have been reduced from the order of 20 ppm to less than 5 ppm when the softener is operated at rating.

Fig. 3 illustrates the stirring mechanism assembly as applied to a hot-process softener which is installed through the head of the sedimentation tank.

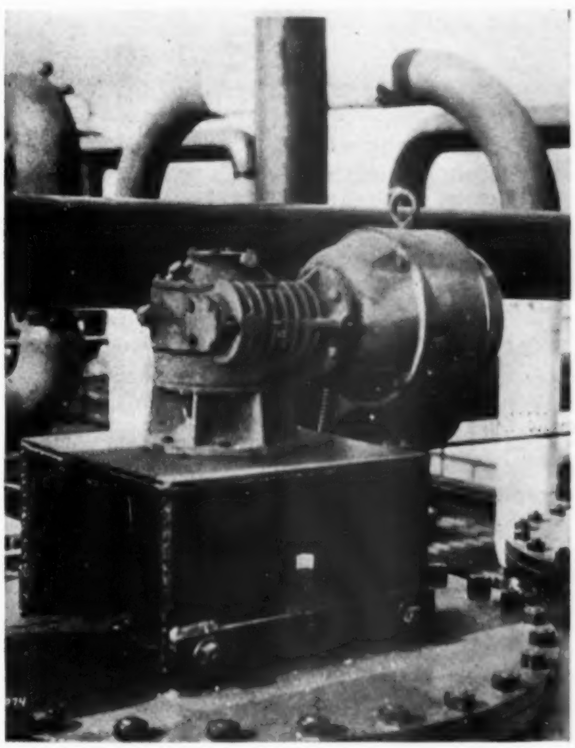

Fig. 4.—Installation of stirring mechanism on top of sedimentation tank showing gear reducer and driving motor

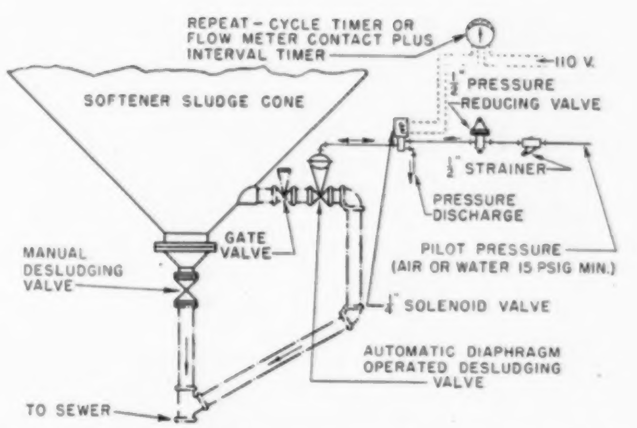

Fig. 5—Details of diaphragm-operated automatic desludging valve installation

Fig. 4 shows motor and reduction gear in an actual installation.

Automatic Sludge Blowoff

It is desirable to have an accumulation of sludge in the apex of the sludge cone from which the pump or eductor will take fairly well concentrated sludge. In order to maintain this concentrated slurry pool it is highly desirable that the sludge be delivered to waste in small quantities, but at frequent intervals. To accomplish this objective, it is generally recommended that automatic sludge blowoff equipment be incorporated in the design. Fig. 5 illustrates a method by which this may be accomplished and Fig. 6 shows the automatic sludge blowoff valve in an installation. A motor-operated valve system has also been satisfactorily employed.

With this device a time-cycle control or a contactor on a flowmeter integrator will close the circuit at regular intervals, or at intervals in proportion to the rate of flow of water, opening the diaphragm valve and permitting the sludge to go to waste. The timer is so set that after a predesignated interval the valve is closed and ready for the next cycle.

In high-pressure installations where the greatest degree of clarity is to be obtained the water-conditioning equipments now generally include a means of sludge recirculation, stirring mechanism and either a continuous or automatic sludge blowoff equipment. Results have been exceptionally good. In many cases the turbidity is reduced to such low values that for the ordinary plant it is now possible to utilize water-softening equipment without the use of filters. However, for the relatively high-pressure boiler plant where the best possible results are desired, filters are recommended.

Examples of Performance

The following examples are given to illustrate the performance of sludge recirculation, stirring mechanism alone, or in combination with sludge recirculation. These represent actual tests over considerable period to illustrate average results.

PLANT NO. 1

In this plant located in the South there are installed two 50,000-gph hot-process softeners both operated at rating and equipped with eductors for sludge recircula-

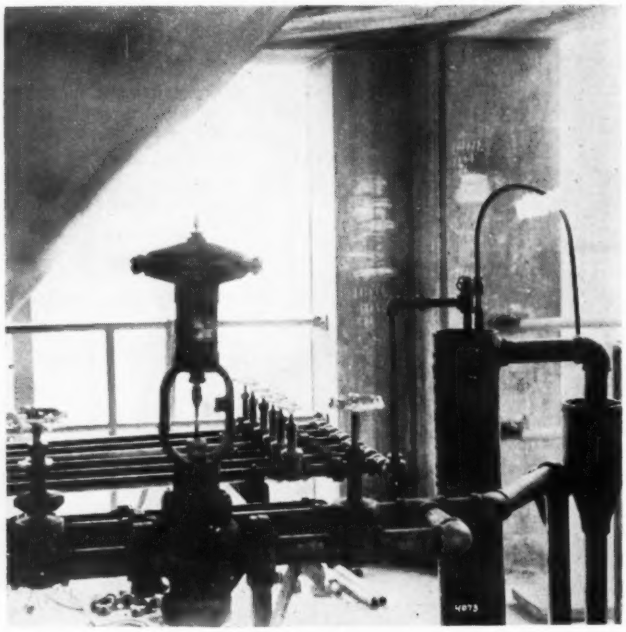

Fig. 6—Automatic sludge blowoff valve installed on hot-process softener sludge cone. Sampling manifold in rear permits analysis of sludge concentration and water condition at various points in the water-softening process

tion, stirring mechanism and automatic sludge blowoff equipment. It is worthy of note that this plant has reported monthly average turbidities of 1.9 ppm to 4.8 ppm for a period of seven months. Turbidity tests are made as a matter of daily routine and the average turbidity for these seven months is 3.7 ppm.

PLANT NO. 2

At another plant operating a 100,000-gph hot-process softener with a tank 30 ft in diameter turbidities as low as 5 ppm, with recirculation of sludge amounting to only 0.7 per cent by volume of the raw water flowing through the unit, have been consistently reported. The performance of this unit was so improved that a project for increasing the filter units to extend the capacity was abandoned due to sharp reduction in the turbidity. The installation is provided with a sludge recirculating pump as well as a stirring mechanism.

PLANT NO. 3

This plant operates a stirring mechanism on a softener conditioning fairly hard water, the hardness ranging from 8 to 20 grains per gallon. The softener is provided with a stirring mechanism only without sludge recirculation. Quantitative tests on the installation when operated at rating indicated a reduction of turbidity down to 5 ppm.

PLANT NO. 4

At a plant in Southern California operating two 50,000-gph hot-process softeners, sludge recirculation and stirring mechanism bring about such a sharp reduction in turbidity that the schedule for backwashing the filters is once in three weeks. This is unusual, but illustrates the efficiency of precipitation and the high degree of clarity of the effluent from the hot-process softener sedimentation tanks.

It is also interesting to note at this plant that sludge recirculation was incorporated principally for the reduction of silica utilizing dolomitic lime as one reagent. It was found that this process was so effective it was necessary to reduce the amount of dolomitic lime to avoid getting the silica concentration so low that there was not sufficient silica in the boiler concentrate to combine with the residual magnesium for producing a nonadhering magnesium silicate sludge.

It is evident from the foregoing that the use of sludge recirculation combined with the stirring mechanism and automatic sludge blowoff has been an advance in the design of hot-process softeners to further improve this versatile method of water conditioning. Therefore, it is now generally recommended that sludge recirculation be incorporated in all hot-process softeners for the betterment of results. Generally this sludge is introduced along with the chemicals and sprayed into the steam space for even distribution.

New Assistant Deputy Administrator Appointed

The appointment of N. O. Wood, Jr., as assistant deputy administrator of the Solid Fuels Administration, has been announced by Dan H. Wheeler, deputy administrator. Mr. Wood, who has been chief of the field office division, succeeds E. Boykin Hartley.

Mr. Wood entered the government service in 1934 with the Public Works Administration, was transferred to the Bituminous Coal Division in 1940. At the expiration of the Bituminous Coal Act, he became chief of the inspection branch of the Solid Fuels Administration for War and was later named chief of the field office division of the Administration.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1946 Water Tube		1945 Water Tube		1946 Fire Tube		1945 Fire Tube	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	173	1,110,924	96‡	534,669‡	113	154,064	50	60,710
Feb.	197	1,262,520	101‡	481,726‡	126	171,100	75	99,815
Mar.	171	1,356,608	134‡	759,214‡	123	180,532	77	87,266
Apr.	198	1,247,693	85	422,213	110	137,614	78	99,154
May	158	980,004	125	812,989	86	117,554	81	83,285
Jun.	151	980,231	186	1,266,372	99	157,664	90	106,085
Jan.–Jun., incl.	1048	6,937,980	727	4,277,183	657	918,528	451	536,315

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers during this period Jan. to Jun. (incl.), 1946, 60,346,000 lb per hr.; in 1945, 42,602,000 lb per hr.

Mechanical Stoker Sales†

	1946 Water Tube		1945 Water Tube		1946 Fire Tube		1945 Fire Tube	
	No.	Hp	No.	Hp	No.	Hp	No.	Hp
Jan.	61	35,757	42‡	18,390‡	185	23,625	187	25,299‡
Feb.	73	41,362	55‡	22,182‡	175	27,708	164‡	20,893‡
Mar.	93	45,496	86‡	32,284‡	181	28,071	237‡	32,614‡
Apr.	94	45,914	57	21,004	251	42,571	197	27,358
May	101	49,653	101	40,470	202	30,933	240	32,456
Jun.	76	42,459	78	33,644	233	32,815	246	34,183
Jan.–Jun., incl.	498	260,641	419	167,974	1,227	195,723	1,274	168,933

† Capacity over 300 lb of coal per hour. ‡ Revised.

Marine Boiler Sales

	1946 Water Tube		1945 Water Tube		1946 Scotch		1945 Scotch	
	No.	Sq Ft*	No.	Sq Ft*	No.	Sq Ft	No.	Sq Ft
Jan.	2	11,276	335‡	1,400,090‡	1	590	6	1,073
Feb.	—	—	34	178,726	—	—	5	1,186
Mar.	—	—	49‡	193,124‡	4	1,706	10	7,685
Apr.	18	46,390	16	65,252	1	263	4	2,126
May	4	9,040	22	100,362	1	263	2	526
Jun.	31	17,620	21	114,537	1	520	22	7,605
Jan.–Jun., incl.	55	84,326	477	2,052,091	8	3,342	49	20,201

* Includes water wall heating surface. ‡ Revised.

Total steam generating capacity of water tube boilers sold during this period Jan. to Jun. (incl.), 1946, 674,000 lb per hr.; in 1945, 21,901,000 lb per hr.

By-product Steam Supplements Chemical Recovery in Pulp Making

By A. L. HAMM

Combustion Engineering Company

A review of developments and expansion in the burning of black liquor for chemical recovery and steam generation with the sulphate process of pulp production; together with a discussion of some of the problems involved in the burning of black liquor which is the residue from the digesting of wood.

GROWTH and progress in the paper-making industry over the last fifty years have been phenomenal and have involved a large expansion in the sulphate process, commonly termed "kraft" from the Swedish designation meaning strength. Up until the time of World War I the kraft industry had grown to an annual production of 200,000 tons. Subsequent unprecedented expansion resulted in a capacity in unbleached kraft by 1944 of 4,000,000 tons annually. Bleached kraft pulp, the production of which amounted to almost nothing after the last war, grew to an annual production of over 800,000 tons by 1942.

No attempt will be made here to go into details of this process, but rather to review briefly the development of the recovery unit which serves the dual purpose of recovering valuable chemicals used in the process, and producing by-product steam through burning of the black liquor from the digesters. It is this phase of the process that holds interest for the steam engineers to which this brief review is directed.

For each ton of pulp produced, approximately 3 tons of wood must be cut from the forest. Of this, about half a ton represents bark and sawdust which is available as fuel for wood-burning boilers. The wood is received in bolts and after chipping goes to the digesters where chemical (mostly sodium hydroxide) is added. The mixture is cooked under a pressure of 125 to 150 psi by steam and yields a ton of strong fiber and "black liquor." The black liquor is made of lignins and other wood residue, spent chemical and water, and is a substance washed from the pulp requiring processing for the recovery of the chemical. This black liquor in amounts of 15,000 to 20,000 lb per ton of pulp produced contains from 80 to 85 per cent water as it leaves the digesters, together with sufficient organic matter to serve as fuel for the recovery unit. Its heating value, on a dry basis, is between 6000 and 7200 Btu per lb. The ratio of organic matter to inert chemical varies with the type of pulp being produced, the kind of wood used and, to a lesser degree, with the technique employed. Soft woods, particularly certain kinds of pine, produce higher heat value liquor than hard woods; and, generally, the longer the wood is cooked to produce a better grade of pulp, the lower the heating value per pound dry solids.

To replace the chemical losses resulting from blowing the digesters, washing the pulp, and other losses throughout the system, sodium sulphate (commercially referred to as "salt cake") is mixed in the black liquor before it is burned in amounts up to 300 lb per ton of pulp.

The primary objective of the recovery unit is to recover the chemicals from the black liquor, but in doing so the modern recovery unit produces a very substantial quantity of steam over and above the requirements of the recovery process. Considered as a steam generator, the recovery unit burns fuel having a heating value of 3500 Btu per lb, containing 35 per cent water and 65 per cent solids of which almost half is chemical ash requiring heat for smelting in the furnace. In the heat distribution a substantial part of the heat applied goes to melting chemical and evaporation of water in the fuel. The remainder for steam must be absorbed efficiently and becomes one of the important measures of value of the recovery unit.

Early Practice

In the early days the practice was to dry this black liquor to an ash and smelt out the chemical contained therein. The heat produced from the smelter went mostly to evaporate water without the benefit of steam production. When boilers were later added, little was known as to the most suitable type and arrangement; hence, in the early installations it was common, after a week of operation, to have experienced a progressively decreasing production of steam until at the end of the week the heating surfaces would be badly fouled and gas passages completely plugged, and steam production at a minimum. In general, the recovery room in those days was an extremely dirty and often dangerous place. Like some other industrial problems, it awaited the development of proper equipment and control.

In the late "teens" and again in the 20's attempts were made to solve this problem, but it was not until the early 30's that real progress was made in development of equipment which served as the forerunner of the present modern unit. One of the main difficulties was that the substance serving as fuel is much more complex than coal or oil, that the liquor, as processed, has changing physical and chemical characteristics, as explained above, and that in each phase narrow limits exist in which to maintain control. This applies particularly to the moisture content and the ratio of organic matter to inert chemical in the liquor. Another requirement is that the recovery unit must be operated and kept in step with the rate at which pulp is being produced.

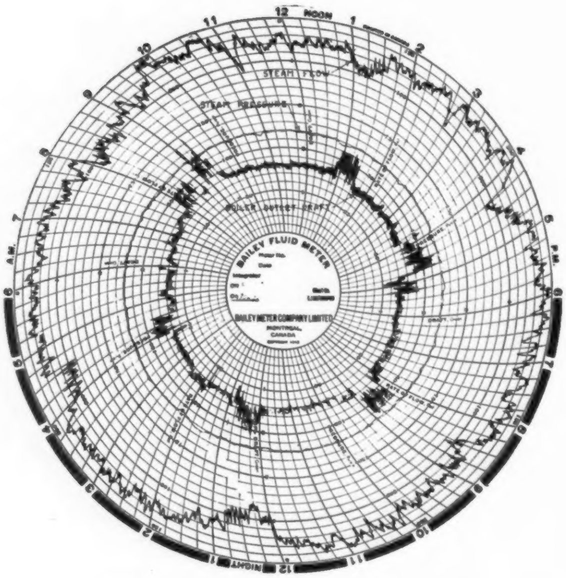

Fig. 1—Typical steam-flow chart

While the liquor leaving the washers contains at least 80 per cent water, this is reduced in the multiple-effect evaporators and in the evaporator scrubber, the latter utilizing heat of the flue gases. For steady furnace conditions the water content of the black liquor delivered to the spray nozzles should be between 30 and 40 per cent. However, if operation of the recovery unit is kept within prescribed limits, results will be comparable to that of fuel-fired power boilers; but, if the limits are exceeded, difficult or almost insurmountable problems are likely to be encountered and steam production will be affected.

Advent of the Modern Type Unit

With the advent of the spray-type recovery unit, a tremendous step forward was made. The cumbersome rotary drier, with its high cost of maintenance, was eliminated. Better drying more favorable furnace conditions and faster rates of burning all contributed to increased liquor consumption and far greater availability for steam production. In the early days of the spray furnaces, the major problem of the recovery operator was keeping the boiler clean or even open enough to permit normal rating. Severe carryover and subsequent plugging of boiler passes required continual cleaning. Failure to properly recognize this problem resulted in a sacrifice of steam production. Improved designs of furnace and boiler, however, plus the acceptance of the practice of removing greater amounts of water from the black liquor before introduction to the furnace resulted in reducing to a marked degree this major problem. Recognition has been given to the fact that a certain amount of diligent cleaning of the boiler will maintain the unit in continuous steady operation and consequent high steam production and chemical recovery, and certainly will safeguard against the serious plugging problem that attended earlier spray-type operation.

The steam-generating section of the modern recovery unit closely resembles a conventional two-drum boiler. The furnace is completely water cooled and the black liquor, under pressure, is sprayed into it through nozzles at each side about halfway up the walls. A slow rocking motion is imparted to the nozzles to afford even distribution of the spray. Because of the pressure and temperature at which it is introduced, the moisture content of the black liquor flashes into steam at the nozzle outlet and expands the size of the liquor particles. This increases the exposed surfaces and almost completely dries the particles in suspension before they fall to the fuel bed at the furnace bottom. Initial ignition is provided by oil torches which provide sufficient heat to place the boiler on the line. Air is supplied to the furnace by ducts and ports. Primary air is admitted a few inches above the floor of the furnace and secondary air below the spray nozzles, while tertiary air, necessary to insure complete combustion, enters at high velocity above the spray nozzles. The primary air supply entering as it does into the fuel bed in which smelting is taking place is necessarily restricted to control the reduction of the chemical. As one of the functions of the furnace is to discharge as much sodium sulphide (Na_2S) as possible from the recovery unit, it is necessary to guard against the combustion of Na_2S to Na_2SO_4; also it is necessary to eliminate the oxygen from the Na_2SO_4 in the liquor. By supplying only a limited amount of oxygen, the carbon will claim its full requirement before any oxygen is available for the sodium sulphide.

Low Fusion Ash Promotes Sticking

Inasmuch as the ash entrained in the combustion gas has an extremely low fusion temperature of around 1400 to 1500 F., there is a strong tendency to stick to heating surfaces and to clog gas passages. To cope with this, vertical tubes, spaced on wide centers, are provided in the high-temperature zone, so that material dislodged from the heating surfaces will fall into the furnace; and provision is made for the continuous removal of deposited material from pockets formed by baf ing in the rear passes. Also adequate soot blowers and accessibility for hand lancing are essential. Because of plugging difficulties, the flue gas air heater has given place to a steam air heater for preheating the furnace air. Electrostatic precipitators are employed to recover chemicals from the

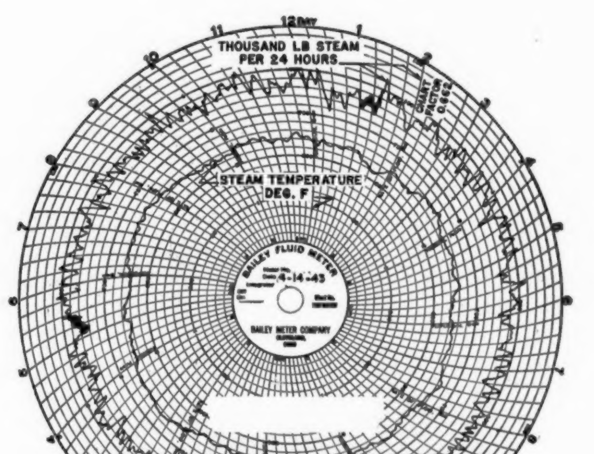

Fig. 2—Despite soda deposits on superheater, fairly constant steam temperature is maintained

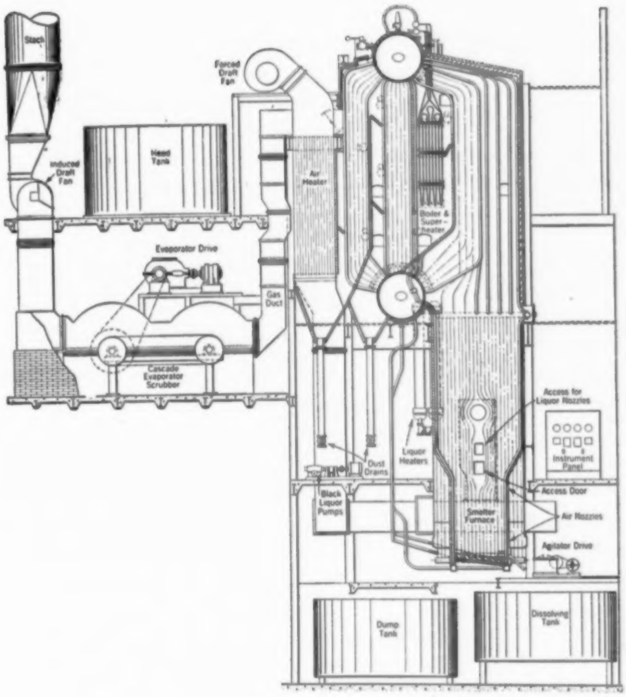

Fig. 3—Vertical tower type unit of 1937

stack gases, thereby reducing the principal source of chemical loss to a minimum.

Increase in Unit Size

The sizes of recovery units have progressively increased up to 300 tons capacity. It might be well to explain here that units are rated in tons of production per day; that is, ability to evaporate water, burn the combustible, melt the chemical and produce steam from the dry solids in the liquor, resulting from a given number of tons of pulp production per day. The early design of recovery units were installed in multiples and of 25 to 31 tons capacity. The early designs with boilers would produce from 8000 lb to 20,000 lb of steam per hour. The largest units in operation to date are capable of producing 120,000 lb of process steam per hour, although this figure is exceeded by some under construction.

With improvement in control and reliability of the recovery unit, as an important part of the steam-generating equipment of a paper mill, it has had to keep pace with the steam condition trends for conventional industrial power boilers. Pressures of 100 psi saturated condition were employed in the early days; the 1930's brought the trend up to the 400- to 600-psi range; and current practice now includes pressures up to 850 psi at the superheater outlet and steam temperatures upwards of 800 F.

The recovery unit in a modern kraft mill calls for skill in operation and care commensurate with the substantial returns possible, which may amount to as much as $1000 a day in chemicals recovered plus steam valued at about $300 (prewar basis) per 100 tons of pulp produced. Close attention to the hourly performance is demonstrated by the steam-flow chart, Fig. 1, taken from a recent installation, which shows the steam obtained from the unit and is typical of 24-hr operation for periods of six months with hardly an interruption. It is interesting to note that the recovery unit from which this chart was taken is one of the main sources of process steam in the mill, as electric power is purchased.

Attention is also called to Fig. 2 showing superheated steam temperature with variations considered well within good recovery performance. This is all the more interesting because the superheater is constantly collecting quantities of soda which is condensed.

Progressive Designs

The first vertical tower type unit is shown in Fig. 3 which was installed in 1937. Experience with this unit led to the arrangement shown in Fig. 4, installed in 1939. The performance of these units governed the principles employed in a series of units ranging in size from the 100 tons to 225 tons during the years of 1938 to 1944. The first 275-ton unit is shown in Fig. 5. From the data and experience with the unit, the 300-ton class, similar to the next lower capacity, is under way for four of the new mills.

The later designs have the benefit of several years of experience and the principles of engineering excellence in stronger walls, better reinforcing, heavy parts, greater heat absorption in parts of the unit, the refinement of controls, improved liquor sprays, care in external space and more instrumentation. There are also large, clean, well-ventilated rooms and proper cleaning equipment.

One of the most promising additions in recent designs is the installation and testing of air-puff soot blowers. A year of operation with these blowers has satisfied the expectation that this would be a distinct advance in recovery practice. Air was known to be a more effective cleaning medium than steam for such service as steam causes the soda to stick to the tubes, which accumulation must then be loosened by additional blasts. But cool air, double-nozzled and released as a blast, was found to do a better job. While the complete story has not yet been

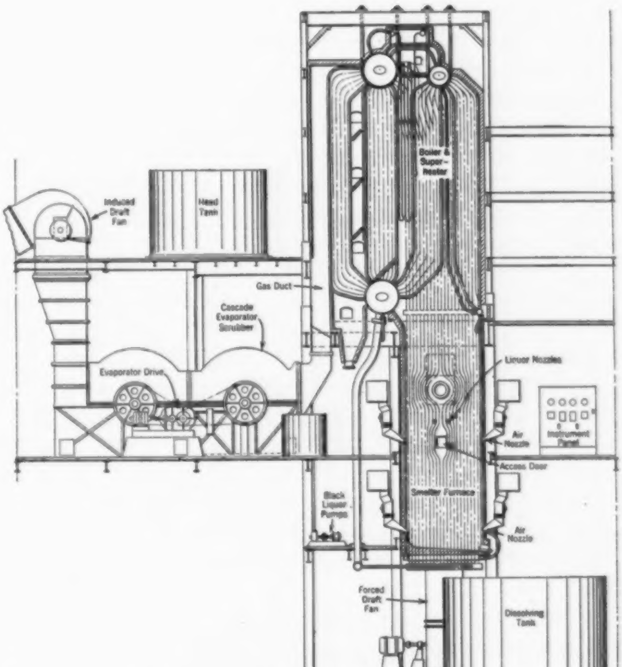

Fig. 4—Unit installed in 1939

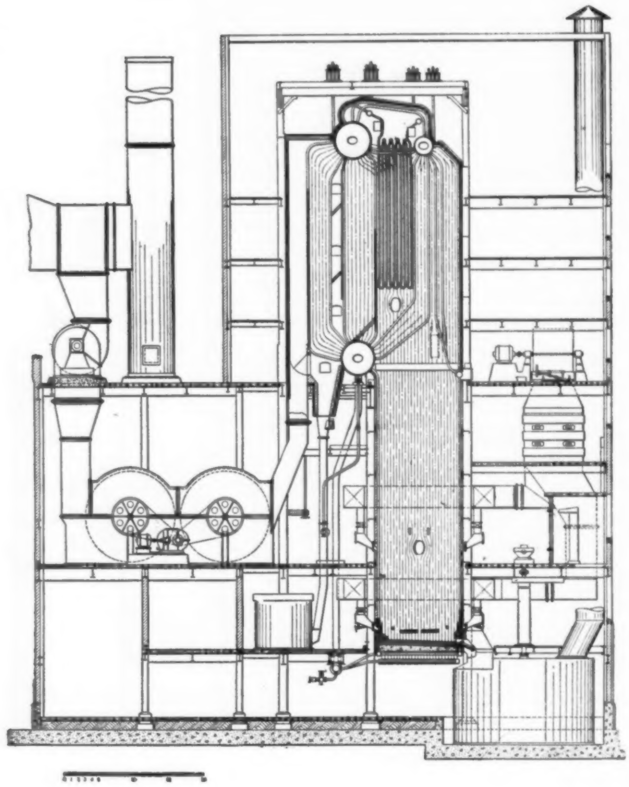

Fig. 5—Late 275-ton unit

told, continued experience demonstrates the value and justification of air-puff blowers for such service.

Throughout the foregoing no mention was made of a second prime duty of the recovery unit. Actually, recovery does not fully define the function of the unit; recuperation provides a better definition. While chemical is being recovered, it is also being recuperated not only by the change of state taking place in the furnace, but also by receiving and adding fresh chemical in the form of sodium sulphate, a granular salt which is received in the recovery room and stirred into the liquor before going to the furnace.

The handling of this salt presents a problem in cleanliness. It is white and very fine, so that it dusts easily through the smallest of openings. Attention is being given to better sealed conveying equipment, to eliminate the last trace of dust-producing sources in the recovery room. After entering the furnace, but before running off to be dissolved in the tank immediately in front of the furnace, this sodium sulphate plus any that carries through in the black liquor is reduced in the low oxygen atmosphere at the bottom of the furnace to sodium sulphide. The chemical in the black liquor, regardless of its state, is melted and runs off through (usually) two water-cooled smelt spouts into a dissolving tank containing what is known as weak green liquor (a solution of all chemical from the recovery furnace in water). When the concentration of this liquor has built up sufficiently, pumping to the chemical reprocessing portion of the pulp mill commences.

Instrumentation has reached a degree of general satisfaction, while leaving room for a few improvements when instrument makers can again give time to special requests.

It will be apparent that it is difficult to separate clearly the discussion of a recovery unit as steam-generating equipment and not parallel the analysis with its main function, that of recovering chemicals. However, it should be appreciated that modern designs for high pressure and temperature steam and large capacity have become of such importance and reliability that the recovery unit is of prime importance when considered as steam-generating equipment in a modern mill.

Points to Remember Concerning CO_2, Draft Loss and Fans

The effect of increasing the CO_2 (decreasing excess air) in the range in which combustion is complete is to reduce both draft loss and boiler exit gas temperature. The furnace temperature (hence, in general, furnace heat absorption) is higher because the heat of combustion is being carried as sensible heat by a smaller weight of gas. But despite the reduction of gas velocity and hence heat transfer rate in the convection sections, the total convection heat transfer and hence temperature drop is sufficiently greater to result in a lower final gas temperature. Thus the effect of raising the CO_2 is to decrease the dry gas loss both by reducing the gas weight and reducing its temperature.

The draft loss or pressure drop for a given system resistance varies approximately as the square of the mass velocity (as density does not vary materially). "Mass velocity" is used rather than linear velocity as the former is constant through the boiler except for infiltration and the latter changes with the temperature. Except for wide ranges in rating, the rate of gas flow varies in direct proportion with the rating; hence the draft loss varies about as the square of the rating. It is useful to remember this in predicting draft losses at several ratings or with different amounts of excess air.

Permissible gas velocities are limited not only by the high power consumption which results from a high draft loss, but also (in coal-fired boilers) by the tube erosion which is caused by impingement of ash or cinder particles at high velocity. Care must be taken to avoid leaks across baffles where a high draft differential exists, as well as the concentration of fly ash in the gas stream at vulnerable points.

Reference to draft losses suggests a mention of the simpler fan laws in so far as they relate to boiler operation. It is sometimes useful to remember that for the same system resistance and a given fan size, the capacity (volume) varies as the first power of the speed, the pressure as the square, and the horsepower as the cube. When the density of the medium (air or gas) changes, the pressure and horsepower vary directly as the density (directly as barometric pressure and inversely as the absolute temperature), if the capacity and speed are constant. This has an interesting implication in connection with constant-speed induced-draft fans; when the fan is started and the steam generating unit is cold, the motor will overload if the damper is not partly closed. Therefore, from the standpoint of protecting the motor as well as for the maintenance of correct furnace draft conditions (with increasing gas temperature) care must be taken in adjusting induced-draft fan dampers when starting up a boiler.

The above notes are excerpts from a recent pamphlet entitled "Modern Steam Generating Equipment," published, 1946, by Combustion Engineering Company.

Improvements in Thermal Efficiencies of Non-Reheating Plants at Higher Operating Conditions

By J. R. FINNIECOME

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This is from a paper before the Institution of Mechanical Engineers, released July 31, 1946, in which the author supplements an earlier paper on the same subject[1] with reference to factors tending to decrease station heat consumption, particularly increase in feed heating for different pressures and total steam temperatures. In the present abstract, calculations and heat balance have been omitted and various sets of curves reproduced to show comparisons.

IN THIS study the well-established "cascade" system of heating has been assumed (see Fig. 1) and consists of: an ejector heater draining through a ball-float tank to the condenser; a drain cooler taking the drains from No. 1 feed heater and leading these ultimately to the condenser; No. 1 feed heater draining to the drain cooler; a gland heater draining to a ball-float tank and then to the condenser; a deaerator (No. 2 feed heater) taking all the drains from No. 3 heater; a boiler feed pump inserted between Nos. 2 and 3 feed heaters; No. 3 feed heater taking the drains from the higher heaters and leading these to the deaerator; and Nos. 4 and 5 heaters, and any subsequent heaters with drains cascading to the next lower heater.

The following additional conditions were assumed:

(1) A temperature rise across the ejector heater of 5 deg F.

(2) A temperature rise across the gland heater of 5 deg F at 600 psig, 10 deg F at 1200 psig and 15 deg F at 1800 psig.

(3) A temperature rise in the feedwater of approximately 50 deg F for the main heaters.

(4) Radiation loss for the heaters as a percentage of the heat fall of the condensed steam of 1 per cent for the first four heaters and 2 per cent for subsequent heaters.

(5) A terminal temperature difference of 10 deg F for each heater plus 20 deg F for pipe radiation and pressure drop, representing a total of 12 deg F for each of the heaters except No. 2 which has 2 deg F.

[1] "Improvements in Thermal Efficiencies with High Steam Pressures and Temperatures in Non-Reheating Plants" by K. Baumann, 1945 *Proceedings*, I. Mech. E. For an abstract of this paper, see COMBUSTION, November 1945.

The results take into consideration the power consumption of the condenser auxiliaries, the boiler feed pump and the draft fans. In addition, the thermal improvement due to the temperature rise in the boiler feed pump has been allowed for and amounts to 0.05 per cent at 1200 psig and 0.10 per cent at 1800 psig when related to 600 psig.

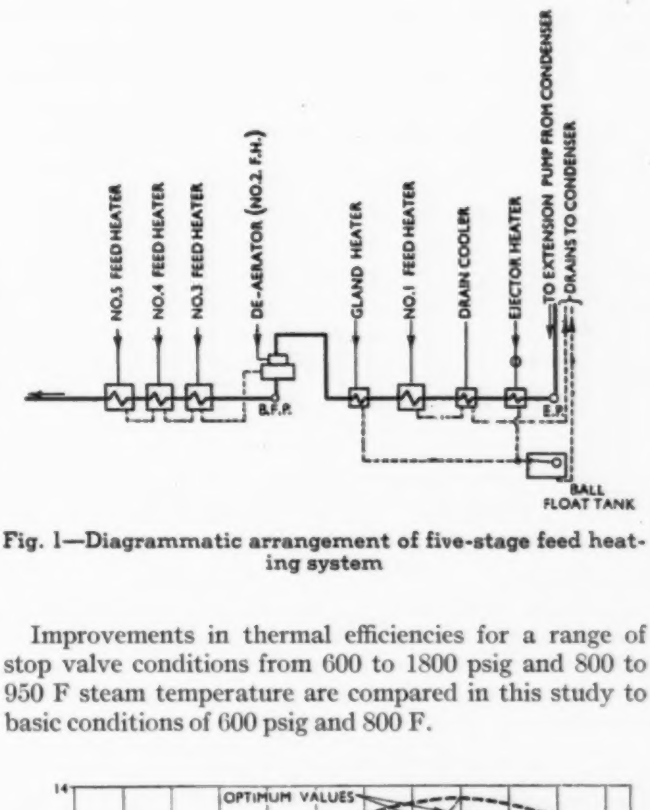


Fig. 1—Diagrammatic arrangement of five-stage feed heating system

Improvements in thermal efficiencies for a range of stop valve conditions from 600 to 1800 psig and 800 to 950 F steam temperature are compared in this study to basic conditions of 600 psig and 800 F.

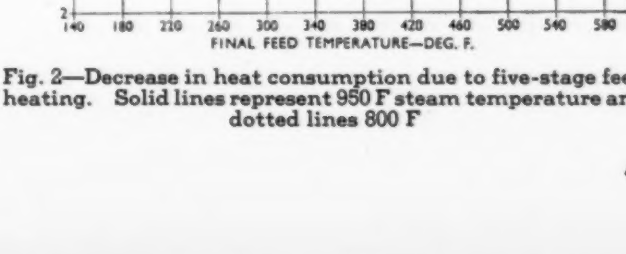


Fig. 2—Decrease in heat consumption due to five-stage feed heating. Solid lines represent 950 F steam temperature and dotted lines 800 F

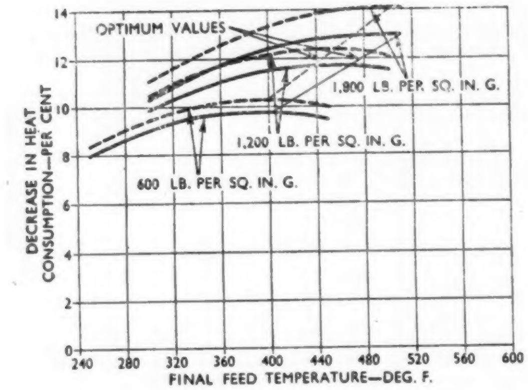


Fig. 3—Decrease in heat consumption due to seven-stage feed heating. Solid lines represent 950 F total steam temperature and dotted lines 800 F

Calculations were made covering the following range of conditions:

1. Pressures of 600, 900, 1200 and 1800 psig.
2. Steam temperatures of 800, 850, 900 and 950 F.
3. Vacua of 28 in. and 29 in. of mercury (based on 30 in. barometer).
4. Five, six, seven, eight and nine stages of feed heating.
5. Final feed temperatures varying from 150 F to 600 F.
6. The economic feed temperature at each pressure.

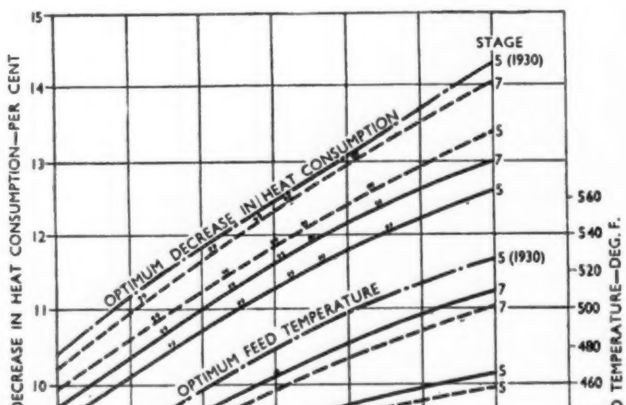


Fig. 4—Optimum decrease in heat consumption and feed temperature for five and seven stages of feed heating for 800 F and 950 F total steam temperatures and five stages of feed heating for 700 F steam and 29 in. vacuum. Solid lines represent 950 F, dotted lines 800 F and broken lines 700 F

Results of calculations, expressed in curves, based on the foregoing assumptions are given in the following:

Decrease in Heat Consumption Due to Feed Heating

Fig. 2 represents the results expressed in decreased heat consumption, for a range of feedwater temperatures from 140 up to 600 F with five stages of feed heating for 600, 1200 and 1800 psig, the solid lines representing 950 F total steam temperature and the broken lines 800 F total steam temperature. Results under like conditions for seven stages of feed heating are shown by Fig. 3. A vacuum of 29 in. is assumed in each case and optimum values are indicated.

It will be noted from these curves that the decrease in heat consumption due to feed heating is appreciably lower at the higher steam temperatures. The optimum decrease in heat consumption and the optimum feed temperature for five and seven stages of feed heating at 800 and 950 F for 29 in. vacuum are shown in Fig. 4.

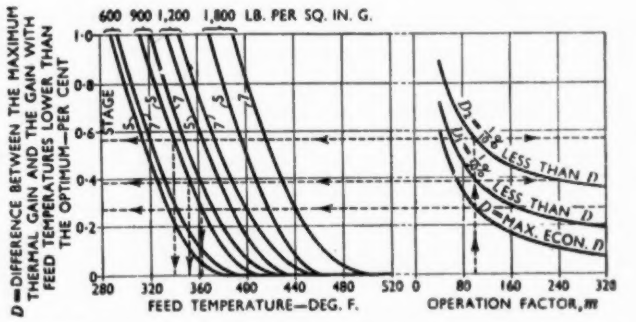


Fig. 5—Economic feed temperature at various stop valve pressures for steam temperatures of 800 to 950 F with five and seven stages of feed heating and 29-in. vacuum

It follows from Figs. 2, 3, and 4 that for the same pressure, the feed temperatures for 800 F steam temperature are slightly lower than those for 950 F and that the decrease in heat consumption for 800 F is appreciably higher than for 950 F. This is due to the greater degradation of heat with higher steam temperatures, resulting in a relatively greater loss of useful work by the steam used for feed heating. The optimum decrease in heat consumption and the optimum feed temperature for five-stage feed heating based on 1927 values published by Dr. H. L. Guy and reproduced by Mr. Baumann in 1930 have been incorporated in Fig. 4 and at 700 F are considerably higher than the latest values for 800 F. The difference between 950 F and 800 F steam temperature for five and seven stages of feed heating is relatively small.

The difference between the maximum thermal gain and

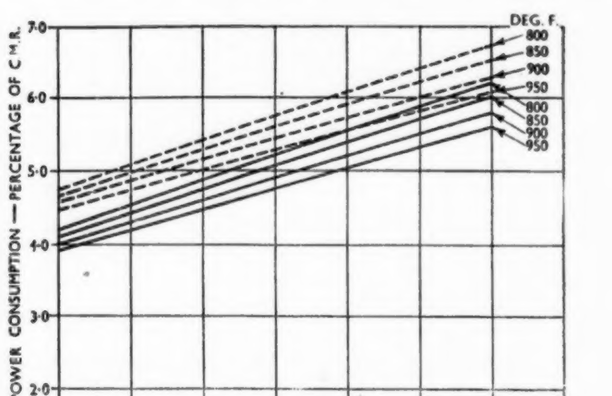


Fig. 6—Power of station auxiliaries at various pressures and temperatures

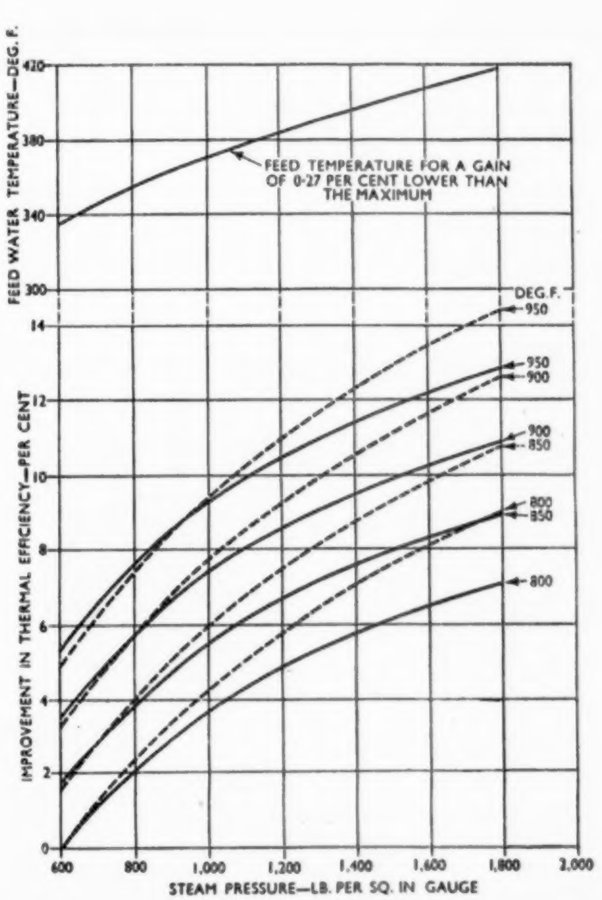


Fig. 7—Improvement in thermal efficiency at various pressures and temperatures related to 600 psig and 800 F, for five stages of feed heating, excluding and including station auxiliaries, and 29-in. vacuum. Solid lines indicate auxiliaries included and dotted lines auxiliaries excluded

the gain with feed temperatures lower than the optimum is indicated in the left-hand panel of Fig. 5 for 600, 900, 1200 and 1800 psig for five and seven stages of feed heating. These values apply with reasonable accuracy to vacua varying from 28 to 29 in. of mercury and for stop valve temperatures from 800 to 950 F.

The graphs in the right-hand panel of Fig. 5 give the difference D between the maximum thermal gain and the maximum economic gain with feed temperatures lower than the optimum for various operation factors m defined as

$$m = \frac{c}{b} \times \frac{l}{r}$$

where
b = calorific value of fuel in Btu per lb
c = cost of coal (shillings per ton)
r = rate of capital charges, per cent
l = load factor, per cent

Excluding station auxiliaries, the ratio of thermal efficiencies relative to the basic conditions of 600 psig and 800 F varies as:

(*a*) The direct ratio of the adiabatic heat drops.
(*b*) The direct ratio of the thermodynamic efficiency of the turbine without feed heating, including corrections for wetness, pressure and temperature, but excluding correction for leaving and exhaust losses with feed heating.
(*c*) The inverse ratio of the difference in total heat of steam at stop valve and sensible heat in entering feedwater.
(*d*) The inverse ratio of steam consumption with feed heating expressed as a percentage of the work done.

Fig. 6 shows the power for station auxiliaries at various pressures and temperatures, inclusive of condenser and boiler feed pumps and fans, the solid lines representing river condensing water and the broken lines cooling towers.

Allowing for a reduction in improvement in thermal efficiency resulting from an increase in gland and other losses at temperatures above 800 F, and applying the values of 5 per cent at 600 psig and 15 per cent at 1800 psig, as recommended by Mr. Baumann in 1945, one obtains the following for the improvement in thermal efficiency at higher temperatures:

(*a*) Excluding auxiliaries, 0.33 per cent for every 10-deg rise at 600 psig and 0.32 per cent for every 10-deg rise at 1800 psig, giving an average of 0.325 per cent for every 10-deg rise for the pressure range.
(*b*) Including auxiliaries, 0.35 per cent for every 10-deg rise for a pressure range of 600 to 1800 psig.

These improvements for stop valve temperatures apply to vacua varying from 28 in. to 29 in. of mercury. The improvements in thermal efficiency, both excluding and including station auxiliaries are shown for vacua of 28 in. and 29 in. in Figs. 7 and 8, respectively.

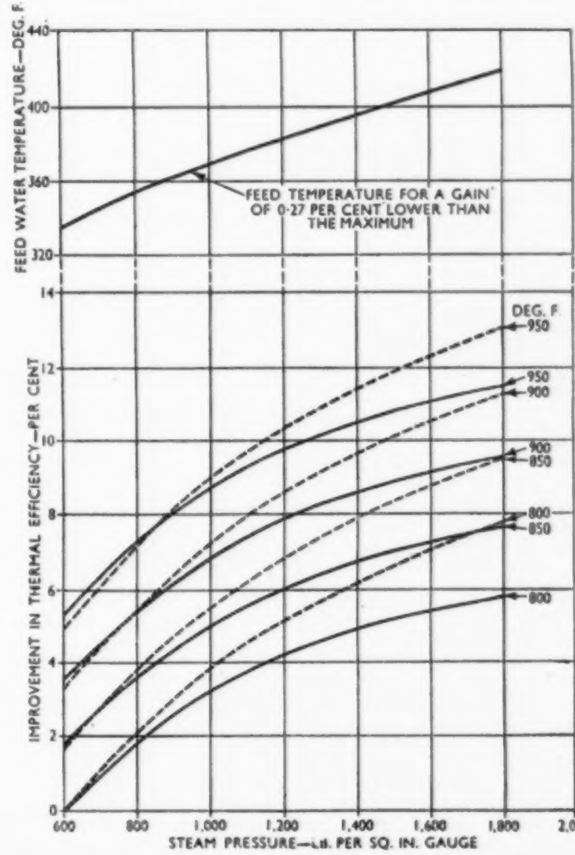
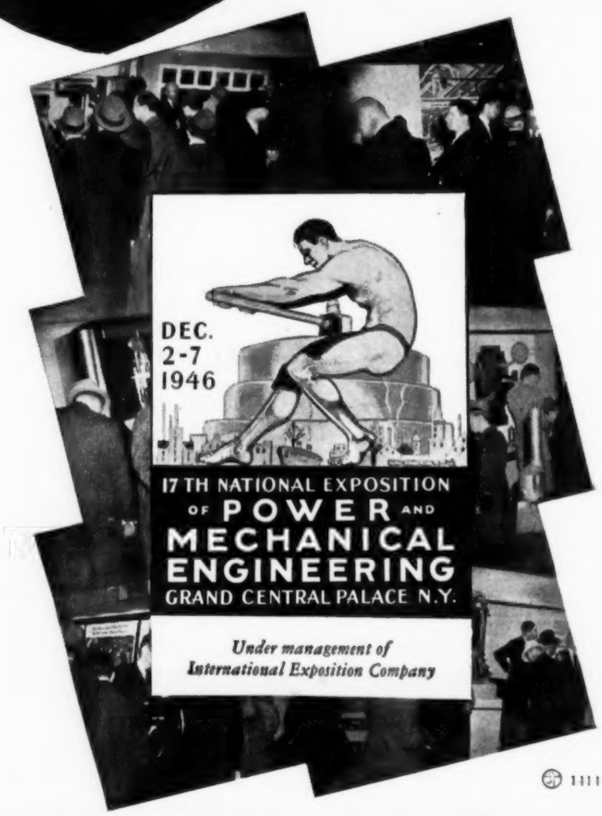


Fig. 8—Improvement in thermal efficiency at various pressures and temperatures related to 600 psig and 800 F for five stages of feed heating, excluding and including station auxiliaries and 28-in. vacuum. Solid lines include auxiliaries for cooling tower conditions and dotted lines excluding auxiliaries.

YES, the 1946 Power Show will feature the exhibits of over 350 manufacturers — all presenting the newest developments in power equipment. Come and study the displays, see the demonstrations. Discuss your problems first-hand with the informed representatives of exhibitors. Learn how you can improve power production and power utilization in your plant.

This is *your* show. General public is not admitted. Attendance only by invitation or registration. Bring your staff with you.



17th NATIONAL POWER SHOW

GRAND CENTRAL PALACE, NEW YORK • DEC. 2-7, 1946

A 5000-Kw Standard Power Plant

By FRANK J. RUDDEN
Westinghouse Elec. International Co.
and
A. MATIUK
Ebasco Services Inc.

THIS 5000-kw standard power plant, an outgrowth of the unit power plants developed during the war to provide electrical power in devastated areas abroad, is designed for peacetime application under widely varying climatic conditions. Containing a boiler, turbine-generator, pumps, wiring, piping and other essentials, such units relieve the operating company from coordinating the complicated unmatched apparatus occasionally found in central generating stations.

While the plant is considered "standard," this term could be misinterpreted to indicate that it is impractical to make certain minor revisions in design to fit the plant to a particular locality or to meet unusual service conditions. This is not true. It was recognized very early in the design stage that these plants were to be international in character, and, as such, might be installed anywhere—from a location at sea level to an installation high in mountainous country. Excellent makeup water might be available, or even the poorest kind of water would be almost nonexistent. Available fuel might be oil, gas, wood, peat, high-grade bituminous or a lignite. To complicate the problems associated with temperature, Siberia would compete with Brazil. The plant was therefore designed with a high degree of flexibility to allow a surprising amount of "tailoring" for operation at maximum efficiency in a specific location or under unusual conditions, and in most cases it is also possible to incorporate certain modifications or special features desired by the user.

Engineered by Ebasco Services Inc., of New York for the Westinghouse International Company, the plant utilizes only one boiler to supply the steam requirements of one turbine, thereby taking advantage of the fact that the design and fabrication of modern steam generators of reputable manufacture have been continuously improved to the point where their availability is now essentially equal to that of the steam turbine, particularly where the units have been so coordinated as to remove the possibility of imposing destructive overloads on the boiler.

For certain installations, however, this may not be possible or desirable, as additional boilers to serve either as standbys or to furnish process steam requirements may be necessary. To meet such conditions, the plant can be adapted to include additional boilers, the capacities of which would be determined after an engineering study of the user's requirements.

Where there are no conflicting requirements the idea of nonduplication of equipment is extended throughout the plant to include all major equipment, auxiliaries, piping systems and the electrical switchboard. Duplications of standby equipment usually necessary in stations of conventional design together with complicated interconnections are eliminated.

An economic analysis led to the decision that the always important minimum initial cost coupled with maximum overall operating economy throughout the life of the plant would be best served by a generously sized steam generator having a continuous rating of 75,000 lb per hr and operating at a pressure of 450 psi and a total steam temperature of 760 F (750 F at the turbine).

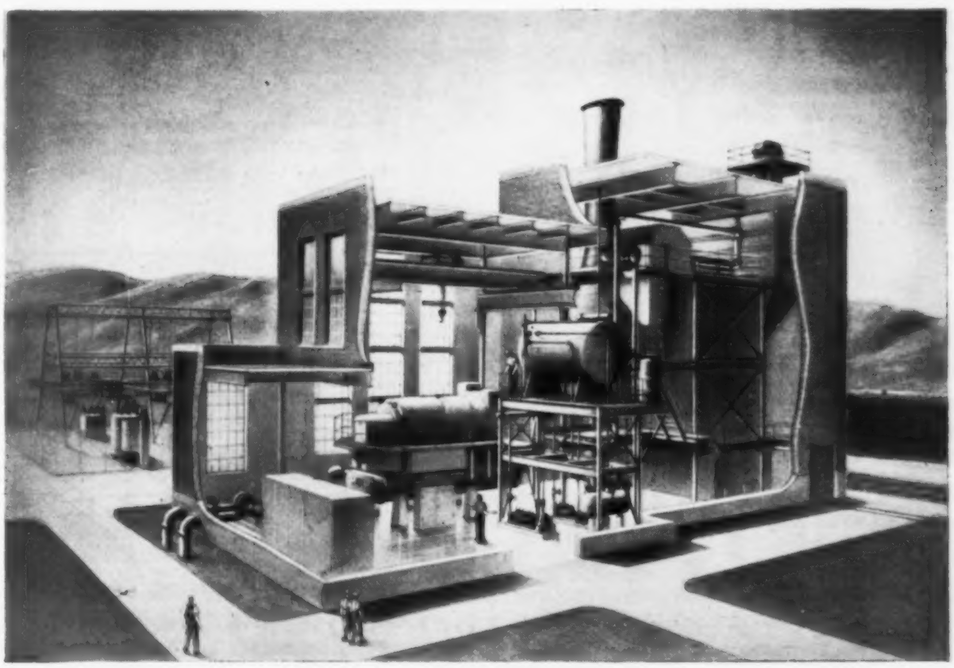


Fig. 1—Cutaway drawing of the 5000-kw standard power plant illustrating unit arrangement

A contribution to overall efficiency was obtained by utilizing a spreader type stoker coordinated with a continuous discharge traveling grate having automatic speed control. An economizer for raising the final temperature of the feedwater to 276 F before it enters the boiler is included as standard equipment. To obtain similar efficiency in the oil-fired unit, an air preheater replaces the economizer.

The boiler is of bent-tube design employing water-cooled walls and designed to operate at an efficiency of 83 per cent even when fired with as poor a fuel as lignite. A boiler efficiency of 85 per cent is obtainable with an oil-burning installation.

In a representative coal-burning installation, coal is delivered to the boiler by means of a motor-driven fuel-handling system which can supply in 8 hr the full load requirements of the power unit for a 24-hr period. During operation, the ashes are continuously discharged into a concrete ash hopper from whence they are periodically transferred to an ash car.

Important items in the feedwater system are the boiler feed pumps. To insure maximum reliability duplicate boiler feed pumps are included, one motor-driven and one turbine-driven, each pump capable of supplying boiler feedwater requirements appreciably in excess of the boiler demand even when operating at maximum peak load.

Because of the many different analyses of water encountered in various districts, particular care had to be taken in the design of the deaerator and evaporator. The evaporator, for example, is designed to produce a vapor containing not more than 5 mg per liter of total dissolved solids. In locations where the available water is particularly bad, equipment for water pre-treatment is included.

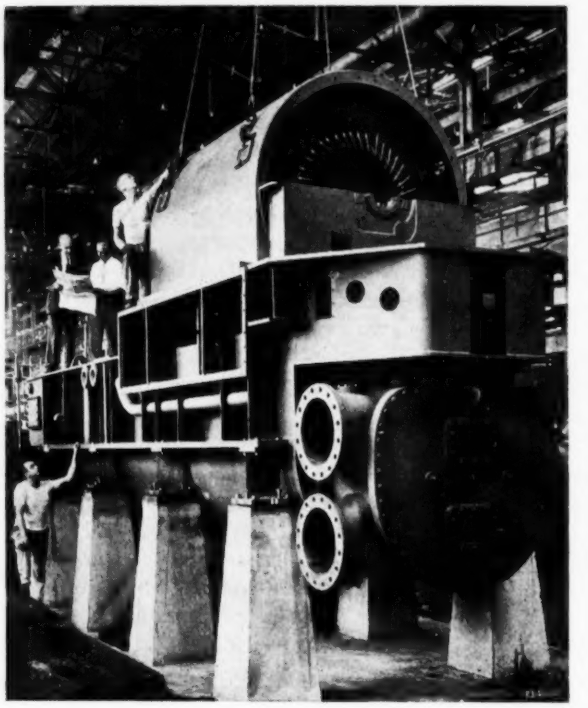


Fig. 2—End view of the turbine-generator showing the method of mounting on the condenser shell

The condenser shell acts as the structural support for the turbine-generator. This design is employed to give

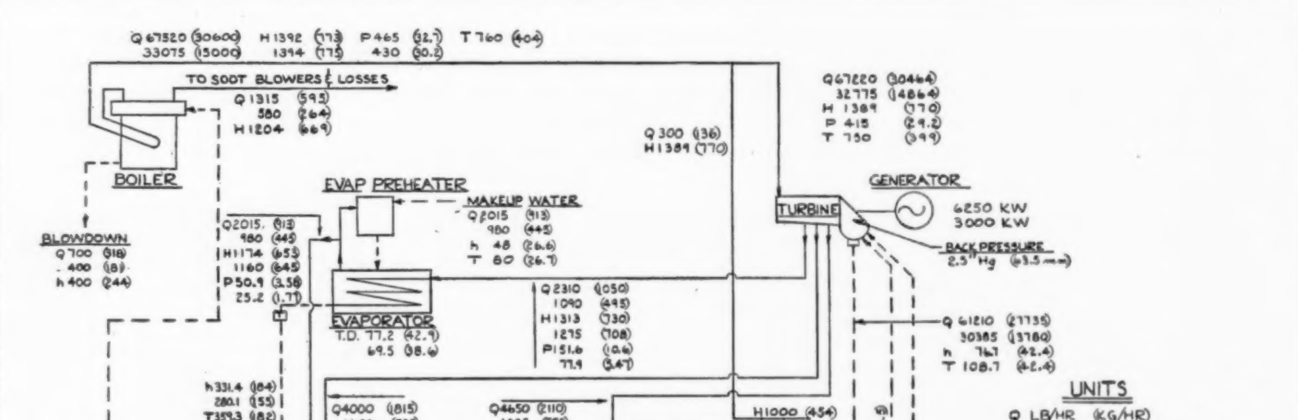


Fig. 3—Heat balance diagram

a compact, integrated unit exceptionally rigid, misalignment-proof and practically vibrationless. The turbine-generator operates at 3600 rpm, and is capable of developing its maximum rating of 6250 kw continuously even under the handicap of a condenser cooling water temperature that in summer might reach as high as 90 F.

Two bleed points are utilized for regenerative feedwater heating and a third point for heating the coils of the plant makeup water evaporator, or alternately for a third stage of regenerative heating.

Since the quality of returning condensate in the feedwater system has a direct bearing on the maintenance problem of the boiler feed pumps, a deaerating type of condenser is used to obtain the best possible oxygen-free condensate.

The electrical system for the power plant is laid out along conventional lines. It so happens that all units supplied to date have been for 13.8 kv generation but with slight modification generation at some other specified voltage is easily obtained without affecting in the least the intrinsic overall design.

Heavy-Duty Switching Equipment

Continuity of operation is assured by standardizing on heavy-duty switch-gear specifically designed for central station use. Both the high-voltage and low-voltage electrical switchboards are of the metal-enclosed, dead-front type. All station auxiliary feeder circuits are protected by automatic air circuit-breakers equipped with both instantaneous trips for short-circuit protection and thermal overload relays with time delay for over current protection.

Always important, but sometimes unintentionally overlooked are the station operators, who are held responsible for plant performance. For these operators, working areas are compact and all control stations are conveniently accessible. Equipment easily reached and in the clear always encourages good housekeeping. This, together with periodic inspection and maintenance, results in a very profitable low record of station outages.

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Rough and Ready Airetool Tube Cleaners can "take on" any tube cleaning job in a steam generating plant and quickly restore operating efficiency.

Even though they are rugged, Airetool Tube Cleaners are fine precision tools. The exclusive New Form cutter design eliminates tracking and tube damage. Airetool motors with their patented Power Seal and Balanced Rotor develop 28% more power, can be loaded down to 50 rpm without stalling and maintain constant torque at low speeds.

Illustrated is Airetool's No. 4325 cleaner with 3270 Forwardly Swing Arm type head for 3" I.D. curved tubes of short radii. Other Cleaners are available in sizes for tubes ½" to 24" I.D.

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Airetool Tube Expanders are designed to perform specific tube rolling jobs—we have the right expander for every job. Airetool Expanders are built of heat-treated steels which maintain a uniform hardness and grain structure throughout each tool.

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A.S.M.E. Fall Meeting at Boston

The program has been announced for the Fall Meeting of the American Society of Mechanical Engineers, to be held in Boston September 30 to October 3, inclusive.

Following registration on Monday morning the meeting will open with a luncheon in the Georgian Room of the Hotel Statler at which addresses will be made by Governor Tobin of Massachusetts and President Yarnall. "Opportunities for Engineers in New England Industry" will be discussed by F. S. Blackall, Jr., President of the New England Council. H. M. King will act as toastmaster of the luncheon.

There will be morning, afternoon and evening sessions throughout the meeting, devoted to heat transfer, management, hydraulics, fuels, wood industries, production engineering, textiles, aviation, education and training, power, metals, machine design, and industrial instruments. In addition there will be numerous plant trips, luncheons and dinners and the banquet on Wednesday evening.

Two papers are scheduled for the Heat Transfer Session on Monday afternoon. The first is "Temperature Distribution in a Hollow Cylinder Heated by a Point Source Moving Along Its Axis," by Prof. D. Rosenthal; and the second, "Thermal Properties of Laminated Materials and Their Significance for Uniform Heating," by V. Paschkis and J. L. Finck.

The first Hydraulics Session on Monday afternoon will have two papers—one on "The Shock Produced by a Collapsing Cavity in Water," by M. F. M. Osborne, and the other on "Investigation of Flow in Liquids by Use of Birefringent Solutions of Vanadium Pentoxide," by Phillip Ullyott. At the second session, on Monday evening, "New Hydro Plants for Old Ones" will be discussed by Frank H. Mason, and the "Replacement and Modernization of Original Hydraulic Turbines at the Vernon Plant of the Connecticut River Power Company" will be described by G. F. Crowe.

"Twenty Years of Progress in Industrial Oil Firing," by Rene J. Bender, and "Packaged Boilers," by Martin Frisch and H. H. Hemenway, will constitute the papers at the first Fuels Session on Monday evening. At the second session on Tuesday morning there will be a Panel Discussion on Single-Retort Underfeed Stokers, led by Ollison Craig, following which colored motion pictures of Pulverized Coal Furnaces will be shown by Otto de Lorenzi.

Two papers are scheduled for the Power Session on Thursday morning. These are "The Removal of Deposits from Steam Turbine Passages," by Glenn B. Warren, and "A New Process for Removing Dissolved Silica from Water," by Walter B. Leaf.

Of general interest will be a paper on "An Immediate Measure to Strengthen the Professional and Economic Position of the Engineering Profession," by C. W. Ransom, and another on "Collective Bargaining for Professional Personnel," by Raymond L. Forshay. Also, at the Thursday luncheon H. A. Winne, of General Electric Company, will discuss "Power—Where do we go from here?"

At the Students' Night Dinner on Tuesday, President-Elect Eugene W. O'Brien will address students on the theme "Places to Go and Things to Do."

The speaker at the banquet on Wednesday evening will be A. C. Klein, Engineering Manager of Stone & Webster Engineering Corp., whose subject will be "Engineering in an Atomic Age." Honorary membership in the Society will be conferred upon Past-President Ralph E. Flanders and Irving E. Moultrop.

Among the scheduled plant inspection trips will be a visit to the Quincy Market Cold Storage and Warehouse, and to the plant of E. B. Badger & Sons Co., on Monday afternoon; the Maverick Mills on Tuesday morning; the General Electric Company's River Works, Tuesday noon, during which luncheon will be served, and to Harvard University on Tuesday afternoon; B. F. Sturtevant Co. on Wednesday noon, and Massachusetts Institute of Technology Tuesday afternoon; and to the new Mystic Power Station of the Boston Edison Company, at Everett, Mass., on Thursday afternoon.

First American Gas Turbine Locomotive

Contract for a pulverized-coal-fired gas turbine for locomotive service has been given the Allis-Chalmers Mfg. Company by the Locomotive Development Committee of Bituminous Coal Research, Inc. It is expected that the new locomotive will be operating within two years.

The unit will be rated at 3750 hp and will be arranged so that the turbine, the compressor, regenerator and gear-drive electric generator will all be mounted on a single base. By employing electric drive it will be possible to run the generator at high rotative speed, so that the relatively small diameter will allow room for auxiliaries and other equipment to be mounted above it.

It is planned to pulverize the coal by passing it with compressed air through a nozzle, employing the system now under development by J. I. Yellott at Johns Hopkins University. This system has already been described in these columns and in several papers before engineering groups.

The tentative design for the turbine calls for an entering gas temperature of 1300 F and a shaft efficiency of approximately 24 per cent.

Water Injection Stimulates Oil Production

More than a million barrels of oil have been recovered since 1936 by water-injection methods from partly depleted oil-bearing formations in eight counties of Texas without drawing on new reserves, the Bureau of Mines has revealed in a new publication tracing the history of water-

Over eighty fellow workers and friends at a dinner in the Duquesne Club, Pittsburgh, on August 27 paid tribute to T. A. Peebles, vice president of Hagan Corporation, as he ended 30 years service with the company. In the photograph he is shown holding a gift from the district offices—an "atmosphere clock" that operates by changes in atmospheric pressure and needs neither electric current nor springs. Seated are J. M. Hopwood, president of Hagan Corporation, and Samuel E. Discher

flooding as a method of oil recovery in North Texas.

The injection of water into oil-bearing formations through selected wells to stimulate production at other wells began on a systematic basis in Texas in 1936, the first permit for such work being granted in December 1936 by the Texas Railroad Commission. By 1940, seven initial projects in three counties had demonstrated the practicability of the method and by the end of 1944, the practice was extended into five additional counties.

A total of 38 water-flooding projects were undertaken in the first eight years in 1970 acres in North Texas and the application of this secondary recovery method has been credited with not only relieving some of the demand for new petroleum reserves, but also with preventing the premature abandonment of producing properties.

Mobile Power Called Upon

With hydro power seriously curtailed because of draught, the Salt River Valley Water Users Association in Arizona recently rented from the U. S. Navy a 10,000-kw mobile power plant which was built during the war for emergency service in war production areas if needed. This plant, which was described at the time of its construction two or three years ago, consists of a train of six cars on which are carried the boiler, turbine, generator, transformers, switches and fuel tank.

Although little use was found for the mobile power plants during the war, as in the case of the Navy's floating power plants, peacetime emergencies have made demands upon them.

Welding Society to Meet at Atlantic City

The twenty-seventh Annual Meeting of the American Welding Society will be held at the Hotel Ambassador, Atlantic City, N. J., on November 17–22, inclusive. A total of 80 technical papers has been scheduled for presentation at the 24 sessions covering 15 divisions of the welding field.

The papers include eleven papers on welding research, thirteen on resistance welding, four on pressure welding, seven on cutting, three on weldability three on railroad applications, three on electrodes, four on production welding three on pressure vessels and storage tanks, three on machinery, three on shipbuilding, four on aircraft, three on structural welding, four on hard facing and three on high alloys. In addition, nine papers will be presented covering a variety of subjects such as the arc welding of cast iron with nickel electrodes, flame-hardening and plant maintenance.

The President of the Society, Wendell F. Hess, will preside at the Annual Dinner on November 21 during which the presentation of medals and prizes will be made. Other features of the meeting will be the

Adams Lecture on Monday evening, November 18, to be given by Dr. Hess of Rensselaer Polytechnic Institute; the University Research Conference on Tuesday evening, November 19; and the annual dinner of the section officers, followed by a session devoted to section activities on Wednesday evening, November 20.

The President's Reception for members and guests of the Society will be held on Sunday evening, November 17, from 5 to 7.

Combustion Organizes Mexican Subsidiary

Combustion Engineering Company, Inc., 200 Madison Avenue, New York, has formed a new company to meet the needs of Mexican expansion programs in the public utility, manufacturing and mining industries for additional steam-generating facilities. The new company, Combustion Engineering de Mexico, S. A. is located at Lopez 1, Mexico, D. F., and is organized to provide sales, technical and installation services in connection with Combustion's full line of boilers, fuel-burning and related equipment. Resident executives of the new company are George C. Siefert, Vice President and General Manager, and Seldon Merrill, Manager of Installation and Service, both of whom have long been identified with the parent organization.

Announces Nucleonics Project

General Electric Co. has announced that work on atomic energy which it is undertaking for the Government includes nuclear research and development at Schenectady, at the Hanford Engineer Works, Wash., and other locations. The Company took over operation of the Government-owned Hanford plant September 1.

Activities will be under the general direction of Harry A. Winne, vice president, and the project will be administered by a three-man Nucleonics Committee consisting of Mr. Winne, Dr. Zay Jeffries and Dr. C. G. Suits, director of the Research Laboratory.

Personals

A. D. Andriola has been appointed chief research engineer of De Laval Steam Turbine Co.

The Spang-Chalfant Division of The National Supply Company has appointed **Charles J. Ramsburg, Jr.**, and **Eugene F. Conroy** as assistant district managers of the New York Office; **Edwin A. Booth** as Pittsburgh district manager, and **Frank W. Morris** as manager of the Tulsa district.

E. A. Tice has joined the Corrosion Engineering Section of International Nickel Company at New York as a corrosion engineer.

Obituary

Grover F. Ilgen, 58, vice president and general sales manager of Airetool Mfg. Company, Springfield, O., died Aug. 27, 1946, in University Hospital at Columbus. He had been associated with the company since its inception in 1930.

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